



**Future Today
Institute**

TECH TRENDS



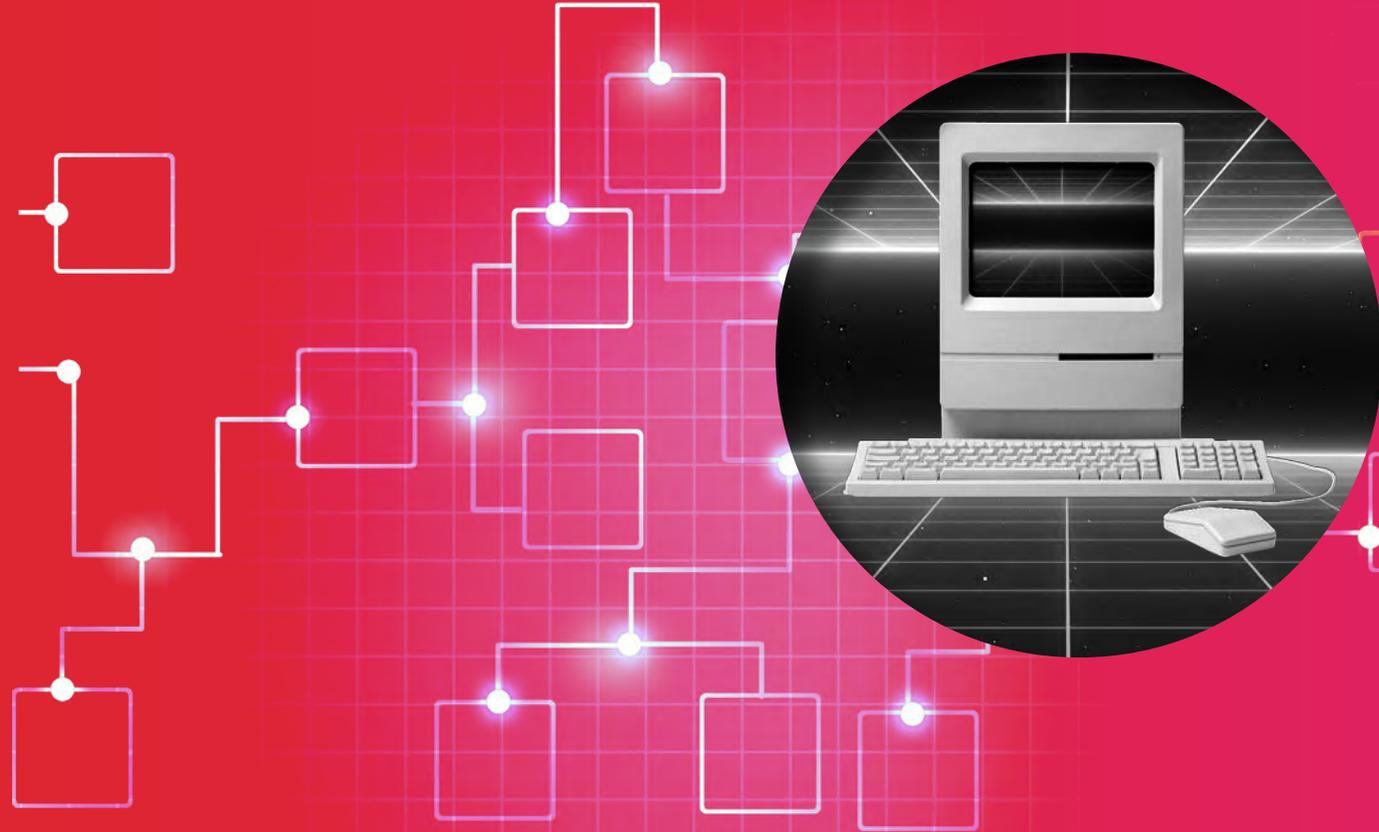
Table of Contents

00	Methodology & Frameworks PAGE 03	05	News & Information PAGE 236	10	Decentralization & Blockchain PAGE 458
01	Artificial Intelligence PAGE 38	06	Health & Medicine PAGE 268	11	Telecommunications & Computing PAGE 509
02	Recognition, Scoring & Privacy PAGE 101	07	Home of Things PAGE 307	12	Synthetic Biology, Biotechnology & AgTech PAGE 543
03	Metaverse, AR/VR & Synthetic Media PAGE 151	08	Policy, Government & Security PAGE 331	13	Climate, Energy & Space PAGE 588
04	Work, Culture & Play PAGE 194	09	Logistics, Robotics & Transportation PAGE 395		



Methodology & Frameworks

The Future Today Institute's process for identifying, tracking and using trends.



At the Future Today Institute, we value learning and strive to make our work accessible to all. We publish this companion to our annual report each year in order to show the process we used to research, model, prioritize and validate trends. We also demonstrate the steps we took to research, develop and pressure-test our scenarios. Showing our work and revealing our quantitative and qualitative data sources demonstrates both the rigor, and the strategic value, of foresight.





Table of Contents

06	Macro Forces and Emerging Trends
08	Overview
09	Seven-Step Forecasting Funnel
10	Time Cone
11	How to Do Strategic Planning Like a Futurist
12	Scenarios
13	The 11 Sources of Macro Disruption
18	Trend vs. Trendy: Knowing the Difference
19	Identifying Signals and Trends: Fringe Sketching
20	Recognizing Patterns
21	Axes of Uncertainty
22	S-SWOT Analysis
23	Assumptions vs. Knowledge
24	Strategic Foresight
27	Team
32	Trends in Action
33	About Future Today Institute
34	Disclaimer
35	Creative Commons License



Macro Forces and Emerging Trends

For nearly two decades, the Future Today Institute has meticulously researched macro forces of change and the emerging trends that result. Our focus: understanding how these forces and trends will shape our futures. Our 15th annual Tech Trends Report identifies new opportunities for growth and potential collaborations in and adjacent to your business. We also highlight emerging or atypical threats across most industries, including all levels of government. For those in creative fields, you will find a wealth of new ideas that will spark your imagination.

Our framework organizes nearly 600 trends into 13 clear categories, which are being published as separate reports. Each report includes specific use cases and recommendations for key roles in many organizations: strategy, innovation, R&D, and risk.

Each trend offers six important insights.

1. Years on the List

We track longitudinal tech and science trends. This measurement indicates how long we have followed the trend and its progression.

2. Key Insight

Concise description of this trend that can be easily understood and repeated to others.

3. Examples

Real-world use cases, some of which should be familiar to you.

4. Disruptive Impact

The implications of this trend on your business, government, or society.

5. Emerging Players

Individuals, research teams, startups, and other organizations operating in this space. Mature organizations are included when they are producing new contributions.

6. Action Scale

FTI's analysis of what action your organization should take. Fields include:

▶ Watch Closely

Mounting evidence and data, but more maturity is needed. Use this trend to inform your vision, planning, and research.

▶ Informs Strategy

Strong evidence and data. Longer-term uncertainties remain. This trend should inform your strategic planning.

▶ Act Now

Ample evidence and data. This trend is already mature and requires action.

00 01 02 03 04 05 06 07 08 09 10 11 12 13
Recognition, Scoring & Privacy

6
Watch Closely
Informs Strategy
Act Now

4TH YEAR ON THE LIST — 1

Scoring



Scoring systems make assessments beyond just people. Food systems can evaluate nutritional intake for a consumer.

KEY INSIGHT — 2

Scoring systems are leaving an indelible mark on all individuals. For some, scoring systems create advantages and enhanced user experiences. For others, inherent biases and a lack of available data on certain individuals create hindrances and shortcomings. Copious data and frameworks for decision-making are integral for automated systems to work.

EXAMPLES — 3

In the U.S., we have a credit reporting system that measures our creditworthiness. Banks, financial institutions, and others use these scores to determine the likelihood that we might default on a loan or a mortgage. Financial credit scoring is available to all consumers—we can request copies of our financial credit scores, check their accuracy, and correct errors. Now, hundreds of types of data are being harnessed to assign us scores. However, unlike the credit reporting system, which is federally regulated and follows set processes, this kind of data isn't subject to enforceable rules. It can be impossible to find out what our scores are, how they are being calculated, and how to correct inaccuracies.

DISRUPTIVE IMPACT — 4

Advancement in data mining and artificial intelligence promise both new opportunities and potential violations of privacy as businesses and law enforcement implement scoring systems on new platforms. Additional risk comes from China selling its government-funded scoring tools, which can be used on both individuals and corporations, to authoritarian regimes elsewhere in the world. Even as new practical use cases become apparent for scoring of this technology.

EMERGING PLAYERS — 5

- Density
- Piwik Pro
- Wakefit
- Dynamic Yield
- Access Now
- Os Keyes and the University of Washington's Department of Human Centered Design & Engineering
- Amin Karbasi, associate professor of electrical engineering and computer science at Yale University
- Ehsan Kazemi, research software engineer at Google
- Voyager Labs
- Flock Safety

130

© 2022 Future Today Institute

Scenarios Describe Plausible Outcomes

You will find scenarios imagining future worlds as trends evolve and converge. Scenarios offer a fresh perspective on trends and often challenge your deeply held beliefs. They prompt you to consider high-impact, high-uncertainty situations using signals available today.

1. Headline

A short description offering you a glimpse into future changes.

2. Temporal and Emotive Tags

A label explaining both when in the future this scenario is set and whether it is optimistic, neutral, pessimistic, or catastrophic.

3. Narrative

The descriptive elements of our imagined world, including the developments leading us to this point in our future history.

Scenario sources:

The Future Today Institute uses a wide array of qualitative and quantitative data to create our scenarios. Some of our typical sources include patent filings, academic preprint servers, archival research, policy briefings, conference papers, data sets, structured interviews with experts, conversations with kids, critical design, and speculative fiction.

Climate, Energy & Space

SCENARIO

Skin Care for the Anthropocene • Mid-future pessimistic scenario

ENVIRO BLOCK

The climate has changed. Has your skin care?

All-in-one protection from the full range of today's environmental harms.

SPF 150+ Won't clog pores Phthalate-free

Effective defense against*:

Plastic Rain	Microbes
Acid Rain	Ozone
Necrotizing Pathogens	Nitrogen Oxides
Airborne Carcinogens	Carbon Monoxide
UVA/UVB/UVC Rays	Sulfur Dioxide

Scan to receive a personalized formula for your own microclimate.

*These statements have not been evaluated by the Food and Drug Administration. This product is not intended to diagnose, treat, cure, or prevent any disease. Not intended for use in extreme climate crisis zones.

737

© 2022 Future Today Institute



What's the new normal? Most of us feel an urgent need to get back to normal, especially as we continue to witness and endure an unprecedented amount of change. Early this year, Russian President Vladimir Putin waged an unprovoked war against Ukraine, which led to a rapid global response. Switzerland broke with tradition and took a side, freezing Russian assets and denying entry to oligarchs. Anonymous, the global hacker collective, waged a cyberwar against Russia, infiltrating government databases and state propaganda websites.

Within the past 12 months, DeepMind solved a 50-year-old problem in biology, opening up new pathways to drug discovery. AI systems proved that they can generate images and text as well as a human. Facebook and Square changed their names to Meta and Block, signaling a digital land grab in the emerging Web 3.0. The biggest streamers—Netflix, Disney+, AppleTV, Hulu—discovered a formidable competitor in social commerce networks like Shein. Seemingly every day, a new set of signals emerge to challenge our existing mental models.

It might feel pointless to forecast the future past a few weeks or months. But strategic foresight results in preparations, not predictions. Trends invite us to consider alternative outcomes from those we previously imagined. They also unlock something invaluable in each one of us: the ability to re-perceive reality. The act of “re-perception” awakens you to the possibility of a future that differs from your current expectations. It helps you understand that you cannot know all things at all times, and that you should be

curious, rather than absolutely certain, about what you perceive in the present.

Our 2022 Tech Trends Report is designed to help you re-perceive the world so that you can confront deep uncertainty, adapt and thrive. In this 15th anniversary edition, we have analyzed nearly 600 technology and science trends that impact most industry sectors. We created 14 separate volumes, and each report focuses on a related cluster of trends. You will also find vivid scenarios depicting the unexpected ways in which the future might unfold. In each volume, we discuss the disruptive forces, opportunities and strategies that will influence your organization in the near future.

Now, more than ever, your organization should examine the potential near and long-term impact of tech trends. You must factor the trends in this report into your strategic thinking for the coming year, and adjust your planning, operations and business models accordingly. But we hope you will make time for creative exploration. The new normal is unfolding for those who know how to re-perceive signals in the present.

Amy Webb
CEO
The Future Today Institute

The Future Today Institute's Seven-Step Forecasting Funnel

The Future Today Institute's strategic forecasting model uses quantitative and qualitative data to identify weak signals and map their trajectories into tech trends. Our seven steps alternate between broad and narrow scopes, which include: framing your work, identifying weak signals at the fringe, spotting patterns, developing trend candidates, calculating a trend's velocity, developing scenarios, and finally, backcasting preferred outcomes.

The steps of our methodology can be used independently to surface new trends or to generate scenarios, or they can be used to guide your strategic planning process. To identify trends, use steps 1 – 4. To imagine future worlds, use steps 5 – 7.

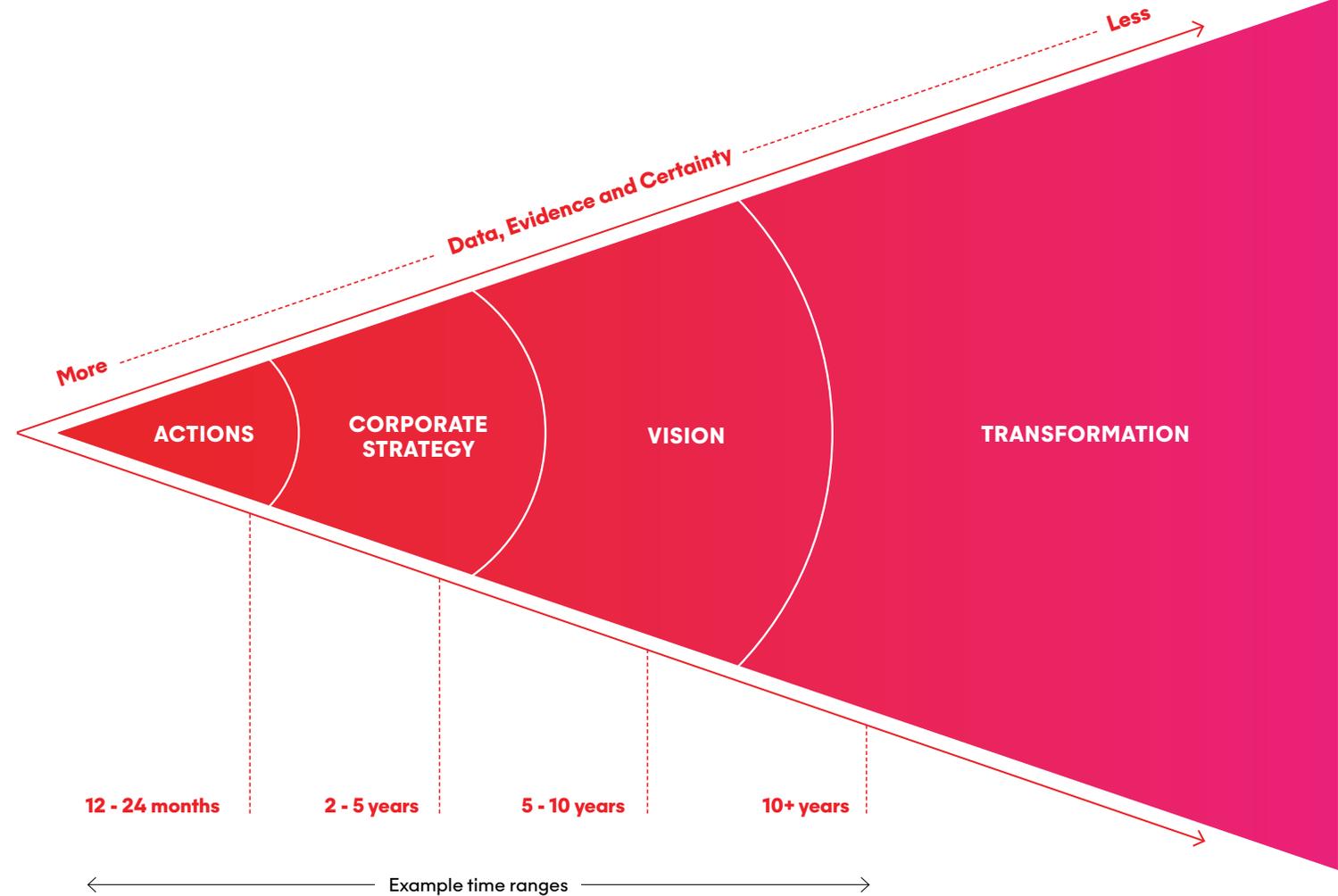


1. **Converge:** Determine your questions, time horizons and stakeholders.
2. **Diverge:** Listen for weak signals at the fringe. Make observations and harness information from the broadest possible array of sources and on a wide variety of topics.
3. **Converge:** Uncover hidden patterns in the previous step. Use FTI's CIPHER framework to identify trends. Look for contradictions, inflections, practices, hacks, extremes and rarities.
4. **Diverge:** Ask questions to learn how the trends you've identified intersect with your industry and all of its parts.
5. **Converge:** Calculate the velocity and trajectory of change that are both internal and external to your organization.
6. **Diverge:** Write scenarios to describe impacts and outcomes in the future.
7. **Converge:** Backcast preferred outcomes. Define your desired future and then work backwards to identify the strategic actions connecting that future to your present.

Time Cone

The Time Cone shows how the range of possible paths forward expands as we look further into the future and the availability of current, reliable, and actionable data decreases.

We map trends on the Time Cone to gain deeper insights into how they could impact a business, government or society.



How to Do Strategic Planning Like a Futurist

For any given uncertainty about the future—whether that's risk, opportunity, or growth—it's best to think in the short and long term simultaneously. As we think about the future, we build a cone with four distinct categories: (1) actions, (2) corporate strategy, (3) vision, and (4) transformation.

We start by defining the cone's edge using highly probable events for which there is already data or evidence. The amount of time varies for every project, organization, and industry. In the Time Cone graphic in this book, we've used 12–24 months as a place to start. Because we can identify trends and probable events (both within a company and external to it), the kind of planning that can be done is tactical in nature, and the corresponding actions could include things like redesigning products or identifying and targeting a new customer segment.

Tactical actions must fit into an organization's strategy. At this point in the cone, we are a little less certain of outcomes, because we're looking at the next 24 months to five years. This area should be most familiar to strategy officers and their teams: We're describing traditional strategy and the direction the organization will take. Our actions include defining priorities, setting resource allocation, making any personnel changes needed, and the like.

Lots of teams get stuck cycling between strategy and tactics, and that makes their organizations vulnerable to disruption. If you aren't simultaneously articulating your vision and transformation, another organization will drag you into its version of the future.

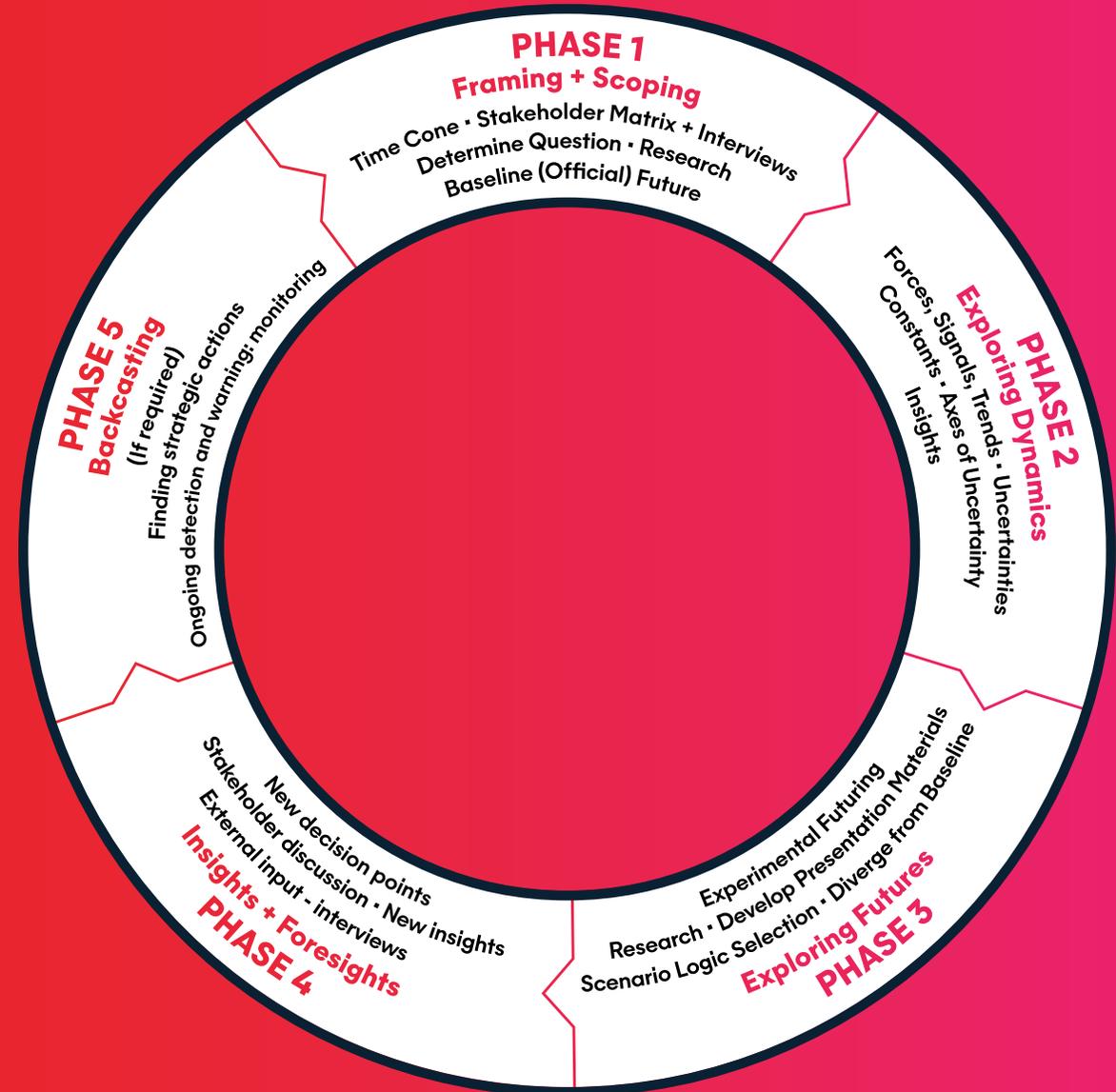
**Think
exponentially.**

**Act
incrementally.**

Scenarios

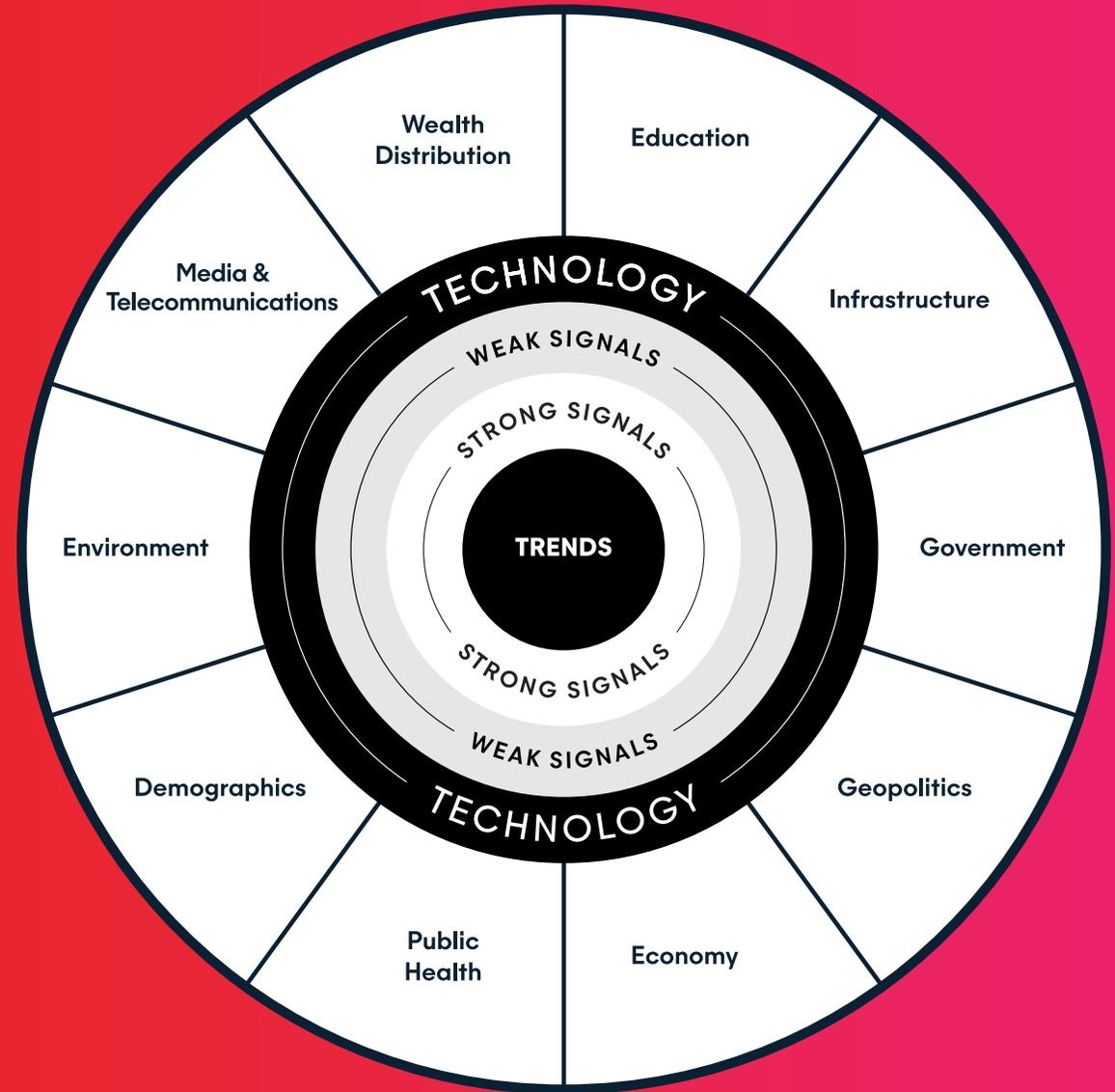
The Future Today Institute's scenario modeling process relies on many rounds of research, analysis, and writing.

Scenarios are narrative snapshots describing possible futures. Scenarios are strategic tools designed to catalyze what-if conversations. They require teams to confront their cherished beliefs, develop shared visions, and sharpen their focus, and refine their expectations. Scenarios do not predict the future. They reduce uncertainty so that better decisions can be made in the present. Done well, scenarios inform what actions must be taken to shape the future.



The 11 Sources of Macro Disruption

Disruption usually stems from influential sources of macro change. The sources represent external factors that affect business, government and society but that are typically outside of our control. We use a simple tool—the 11 Sources—to organize our thinking around each of these sources of change when researching forces, signals and trends.



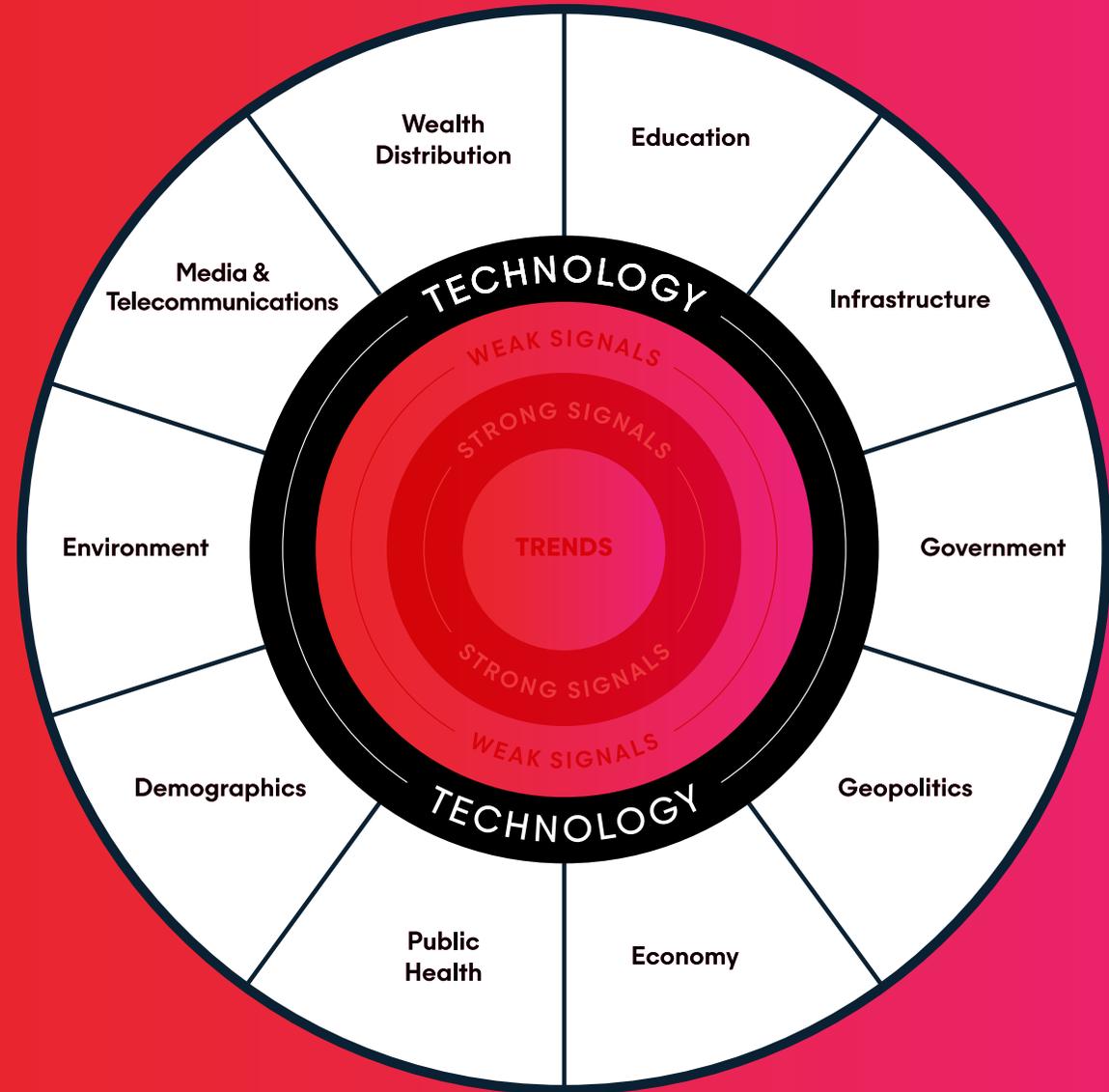
The 11 Sources of Macro Disruption

Macro Sources Shape Our World

These 11 Macro Sources represent external factors that no one entity has control over but that play a critical role in how our futures develop. These factors broadly influence business, governing, and society. They can skew positive, neutral, and negative. These are primary source shifts. Developments in each of these 11 Macro Sources impact the world we live in.

This framework illustrates how disruption tends to stem from 10 major influential sources of macro change, with technology, the 11th source, underpinning all others. When we are analyzing the future of anything, we think about each area of potential disruption.

The result is a diverse set of clear drivers we use to guide our research and analysis.



The 11 Sources of Macro Disruption

Macro Sources Shape Our World

Technology:

We recognize technology not as an isolated source of macro change but rather as the connective tissue linking business, government, and society. For that reason, we always look for emerging tech developments, as well as tech signals within the other sources of change.

Wealth Distribution:

The distribution of income across a population's households, the concentration of assets in various communities, the ability for individuals to move up from their existing financial circumstances, and the gap between the top and bottom brackets within an economy.

Education:

Access and quality of primary, secondary, and post-secondary education; workforce training; trade apprenticeships; certification programs; the ways in which people are learning and the tools they're using; and what people are interested in studying.

Infrastructure:

Physical, organizational, and digital structures needed for society to operate (bridges, power grids, roads, Wi-Fi towers, closed-circuit security cameras) and the ways an infrastructure of a city, state, or country might impact another's.

Government:

Local, state, national, and international governing bodies; their planning cycles; their elections; and their regulatory decisions.

Geopolitics:

The relationships among the leaders, militaries, and governments of different countries, and the risk faced by investors, companies, and elected leaders in response to regulatory, economic, or military actions.

Economy:

Shifts in standard macroeconomic and microeconomic factors.

Public Health:

Changes in the health and behavior of a community's population in response to lifestyles, popular culture, disease, government regulation, warfare or conflict, and religious beliefs.

Demographics:

Observing how birth and death rates, income, population density, human migration, disease, and other dynamics are shifting communities.

Environment:

Changes to the natural world or to specific geographic areas, including extreme weather events, climate fluctuations, rising sea levels, drought, high or low temperatures, and more. (We include agricultural production in this category.)

Media and Telecommunications:

All of the ways we send and receive information and learn about the world. These include social networks, news organizations, digital platforms, video streaming services, gaming and eSports systems, 5G, and the boundless other methods for connecting with each other.

The 11 Sources of Macro Disruption

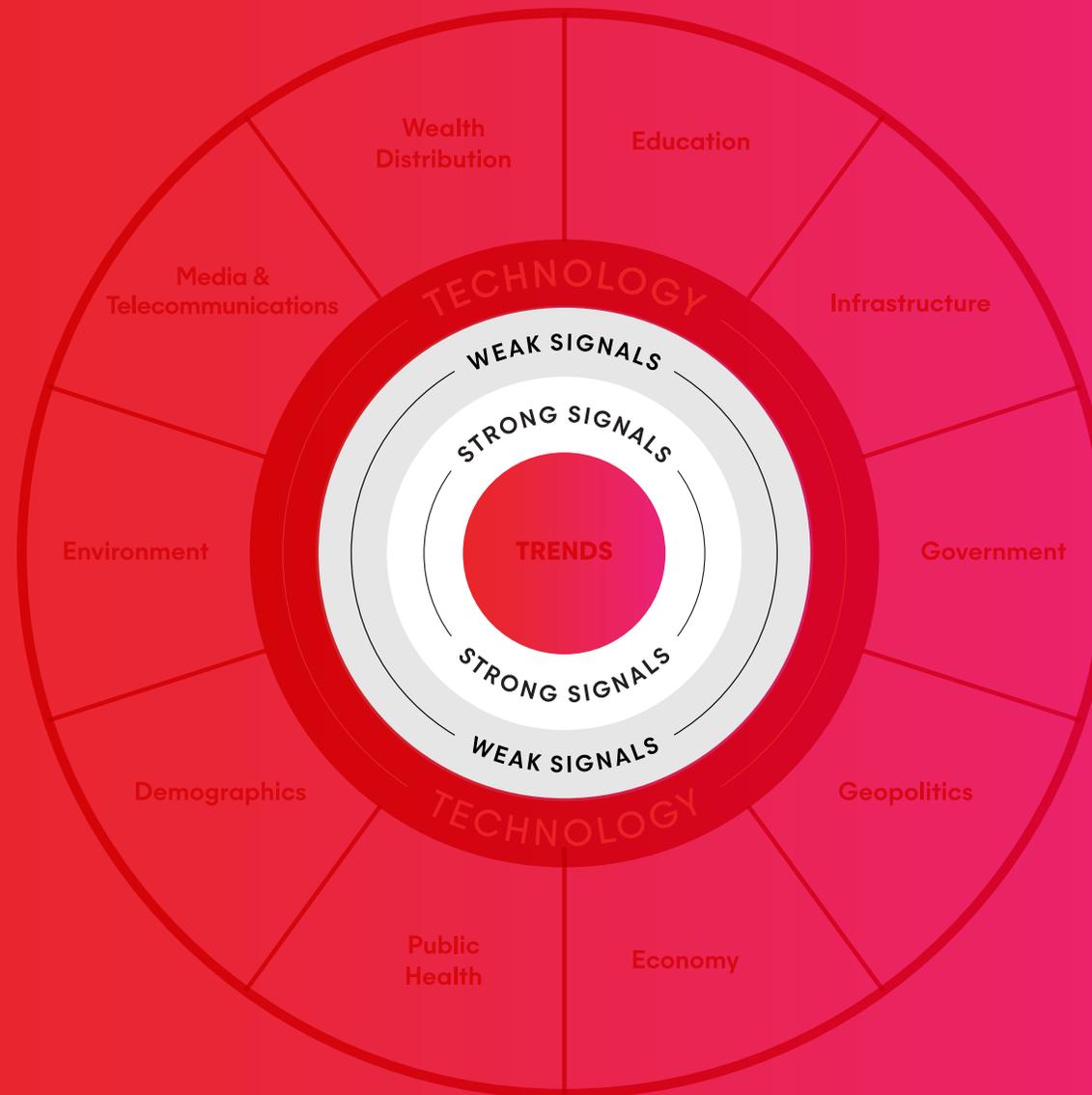
Signals Indicate Emerging Change

Weak Signals are...

- A small innovation, incremental development, or R&D advancement, or other minor development that has the potential to grow as it matures
- A new technology development that has not yet entered the mainstream, or a new market strategy, product, or service entering a noncompetitive space
- Evidence of an existing thing becoming obsolete, or evidence of a novel thing emerging
- A recently revealed problem or state of affairs that does not directly or immediately impact your business

Strong Signals are...

- A bigger innovation, significant development or R&D advancement, or other big development that is maturing
- A new market technology, strategy, product, or service entering a competitive space, where others are likely to follow fast
- Factors that challenge current beliefs or assumptions and have the momentum to mature or grow fast
- Obvious advance warning indicators



The 11 Sources of Macro Disruption

Trends Represent MOVEMENT to the Futures

Main need:

A trend is driven by a main, basic human need, one that is catalyzed by new technology.

Ongoing:

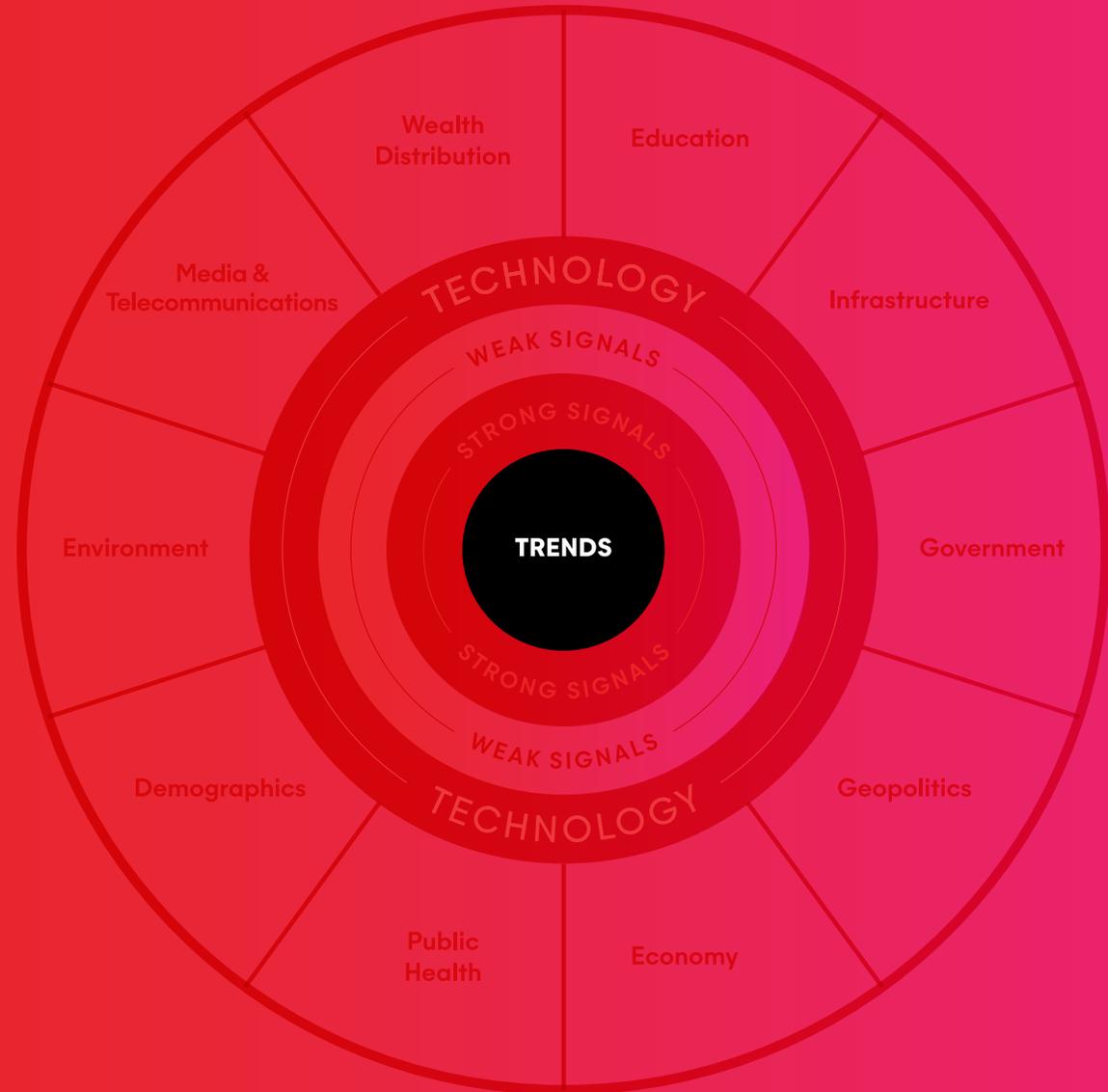
A trend is timely, but it persists over a long period of time.

Vectors:

A trend is the intersecting vectors of (sometimes disconnected) weak signals on the fringe.

Evolving:

A trend evolves as it emerges. Trends are not static.



Trend vs. Trendy: Knowing the Difference

Sometimes it can be a challenge to distinguish between something that is trendy (i.e., a fad that comes and goes) and a genuine “longitudinal” trend that will have significant lasting impact on the world, and on your business. We can validate the latter type of trend by confirming it meets most or all of the MOVEment criteria.

Trendy phenomena (or fads) are much more transient. They appear suddenly, capture our attention, and distract us with intense possibilities—only to burn out just as quickly as they arrived. Fads move along a common cycle—insider discovery, trending on social networks, influencer bragging, media hysteria and mainstream acceptance—until we are disillusioned because the fads never meet our broader expectations.

The output is a verified trend or set of trends that can then be accounted for in the strategic plans of your organization. The MOVE criteria can help you avoid spending time and resources adapting to what may appear to be a strong signal, only for it to prove inconsequential in the near future.



Recognizing Patterns

CIPHER provides a tool to categorize the signals we surface during our Fringe Sketch, but we also use it for our regression models.

Six key factors indicate trends, and they are represented by the CIPHER acronym.

Contradictions, inflections, and practices are the most common. Hacks and extremes tend to be outliers or strong trends when they appear. Rarities are exactly what they sound like: rare and unusual, so when we see them we tend to pay close attention to their influence.

C	Contradictions	Examples that demonstrate opposing or incongruous forces at play simultaneously
I	Inflections	Occurrences that mark a major turning point or establish a new paradigm
P	Practices	Emerging behaviors that are becoming more pronounced or gaining in popularity
H	Hacks	Inventive, unintended uses for tools, technologies, and systems
E	Extremes	Instances of technologies, functions, or concepts being pushed to new limits that might change the nature of their use
R	Rarities	Highly unlikely or unexpected events and phenomena

Axes of Uncertainty

We use a 2x2 matrix—the Axes of Uncertainty—to rapidly prototype short, detailed narratives describing plausible outcomes of high-impact, high-uncertainty events.

We use the Axes to test different uncertainties and variables. We may develop 100 or more scenario possibilities using the Axes, which offers a broad perspective on possible outcomes.

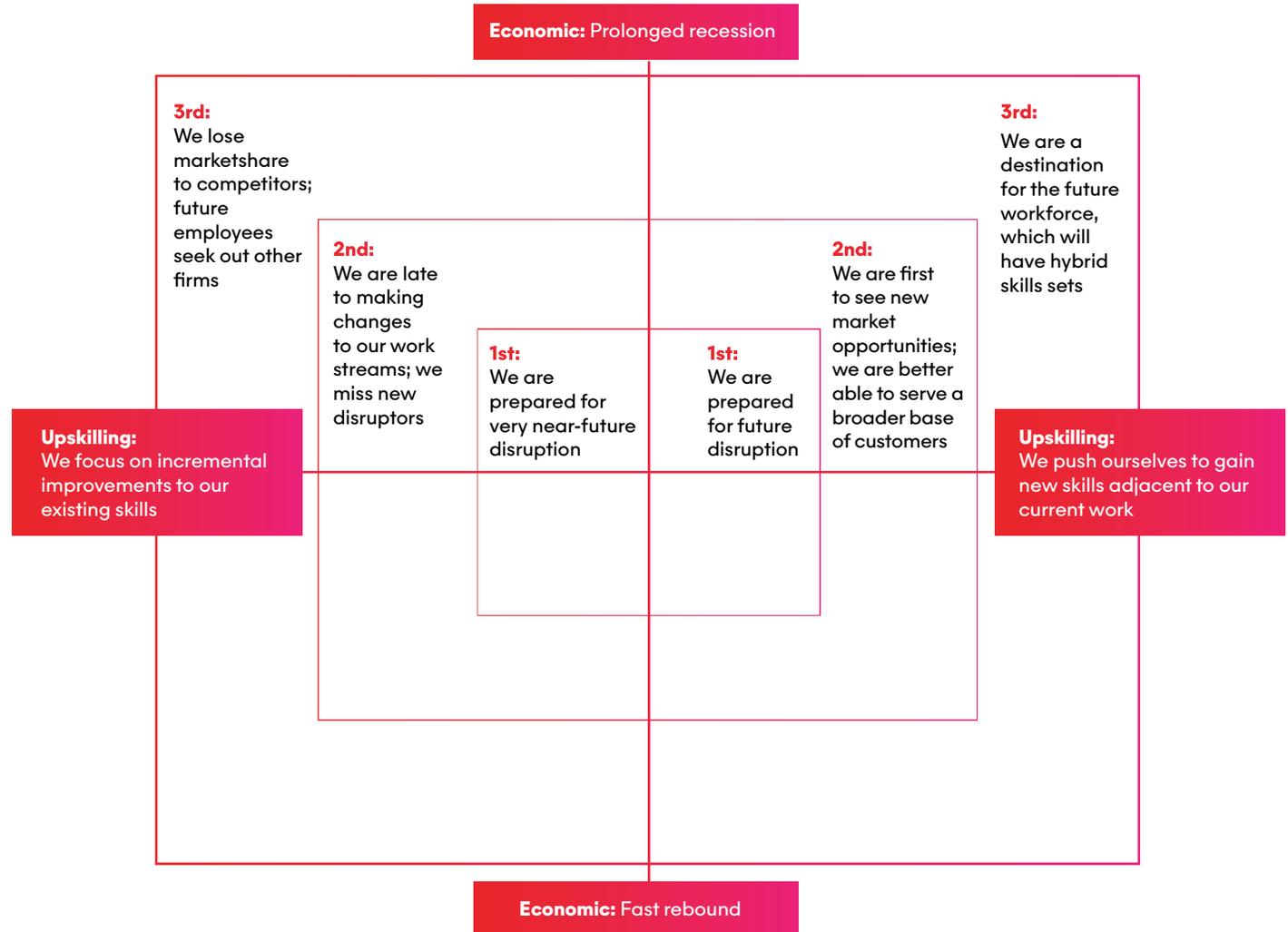
Starting with a prioritized list of signals and trends, additional uncertainties are generated based on macro sources or those that relate to our current project.

Uncertainties are placed on opposite axes to explore what outcomes might emerge. Each quadrant answers “What if these two factors became realities?” We continue probing until we have a short but deep story and finish with a headline describing that future state.

Each quadrant is labeled using time horizon (near-term, mid-term, long-term) and impact (risk, collapse, growth, transformation).

Labeling helps prioritize the quadrant for the next phase of our scenarios work.

Describe what a future state would look like if each of the uncertainties were to happen. Then describe the next (2nd) impact. And the impact of that (3rd).

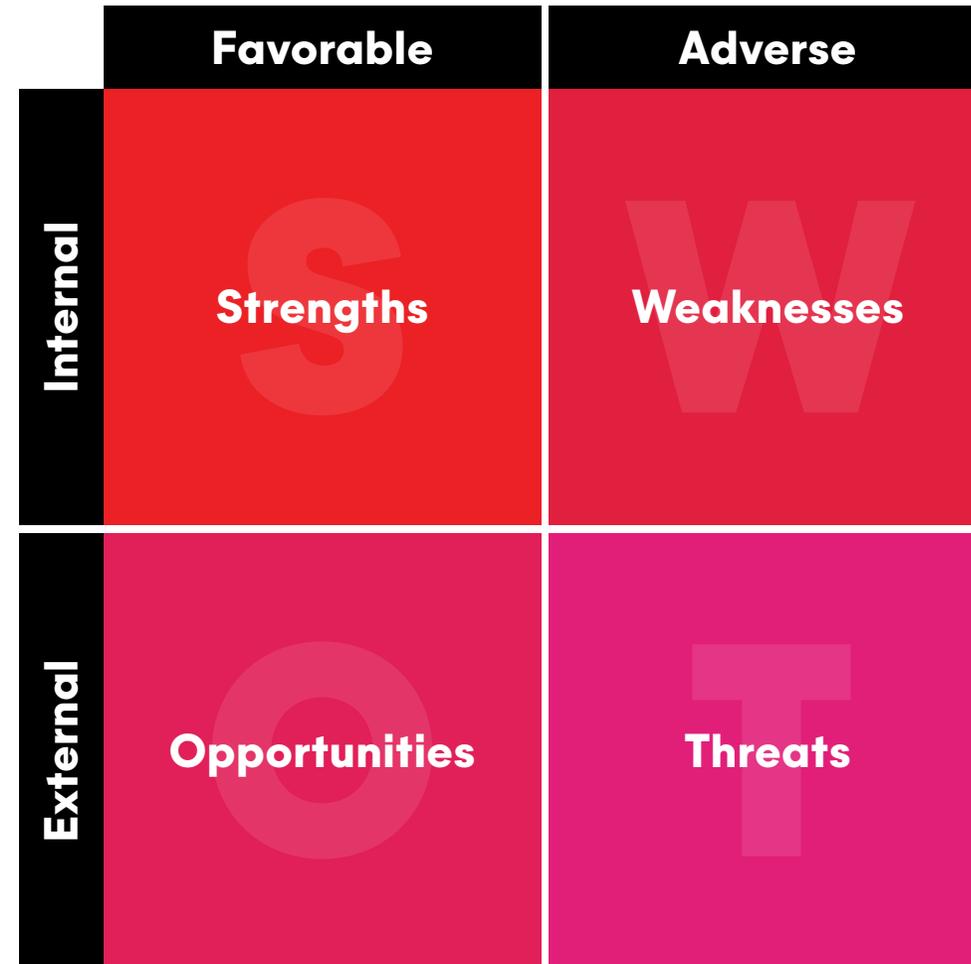


S-SWOT Analysis

We adapted the traditional SWOT analysis as a way to frame scenarios for organizations new to foresight. (Hence, Scenarios-SWOT.) Because this framework is already known to most organizations, it reduces some of the frustration that can sometimes be associated with data-rich scenarios.

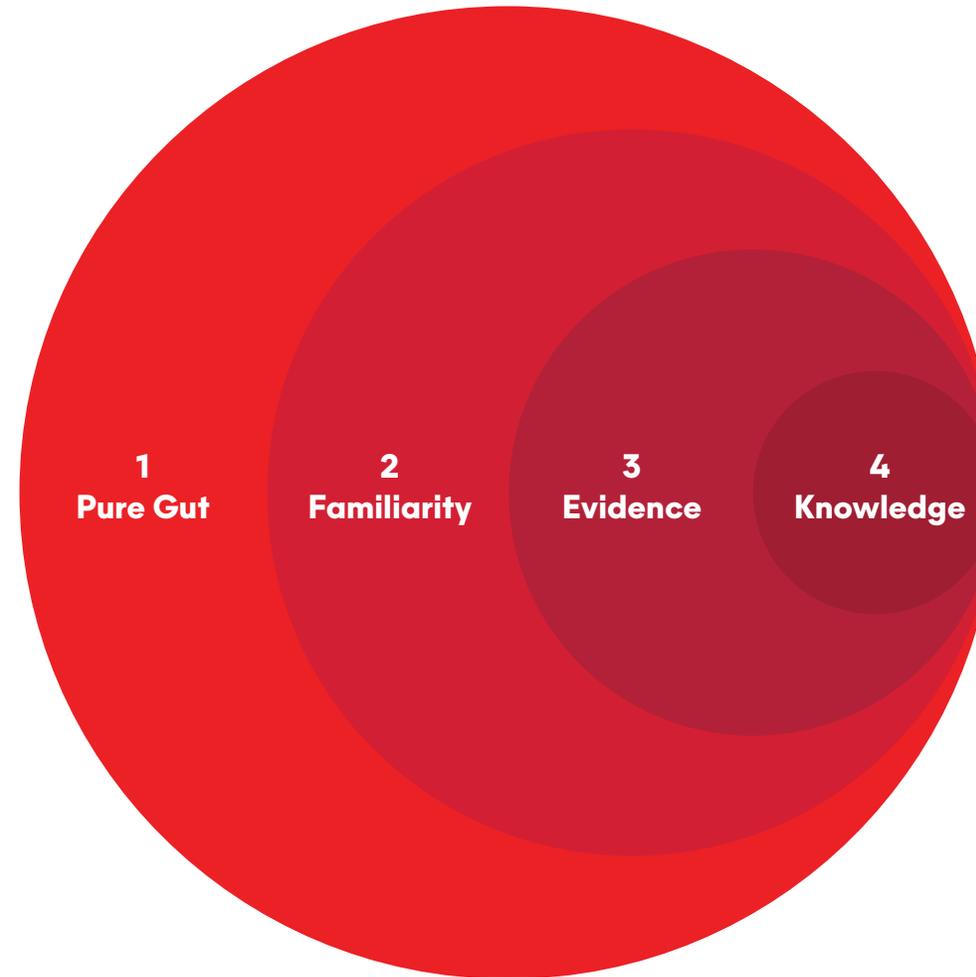
SWOT stands for Strengths, Weaknesses, Opportunities, and Threats, each of which occupies a quadrant, and the quadrants are further classified as internal versus external to the organization, and as favorable or adverse.

In the context of foresight, we use this tool with teams new to scenario writing. It helps them prepare to write scenarios with optimistic and catastrophic framings. A completed SWOT matrix helps teams develop the components to include in narratives. The optimistic scenario will describe a future in which teams capitalize on their strengths and seize the opportunities identified, while a catastrophic scenario will describe a future in which the weaknesses they identified are exploited or prevent them from succeeding, and the threats they surfaced are actualized.



Assumptions vs. Knowledge

This is a tool we use to check our instinctive biases—a scale we call AvK, short for Assumptions vs. Knowledge. It can be used any time an assertion is made to determine whether it's based on fact or feeling. On one end of the spectrum are Assumptions (1), pure hunches that are not supported by any substantial data, and on the other is Knowledge (4), declarations made with ample evidence from multiple sources to back them up. With two intermediate steps—limited evidence or insight but still significant uncertainty (2), and meaningful corroborating data or models but still some doubt (3)—the scale is a great way to keep sentimental bias from clouding our strategy.



1. Pure Gut

- No evidence affirming or negating
- Hopeful thinking
- Intuition

2. Familiarity

- Some evidence
- Some insights
- Lots of remaining questions

3. Evidence

- Mounting evidence
- Models are built
- A few remaining questions

4. Knowledge

- Extensive evidence
- Established models
- Questions answered

Foresight

What is Strategic Foresight?

Strategic foresight reduces uncertainty about the future. It's about preparation, not predictions.

Foresight is a strategic activity that uses quantitative and qualitative data, frameworks and tools to build plausible visions of the future so that management can make informed decisions today.

Accounting data, competitor intelligence, market share, the success or failure of past initiatives, campaigns or products, and consumer research covering near-term supply needs can be accurate in the present, however they are often unreliable predictors of the future. Likewise, presumptions that the future will merely be a continuation of the present does not accommodate the chaos, uncertainty and disequilibrium that develop during periods of rapid change.

Foresight

Foresight Creates Value

33% Higher Profitability

Companies with a dedicated strategic foresight methodology and resources outperformed the average by a 33% higher profitability.

200% Growth

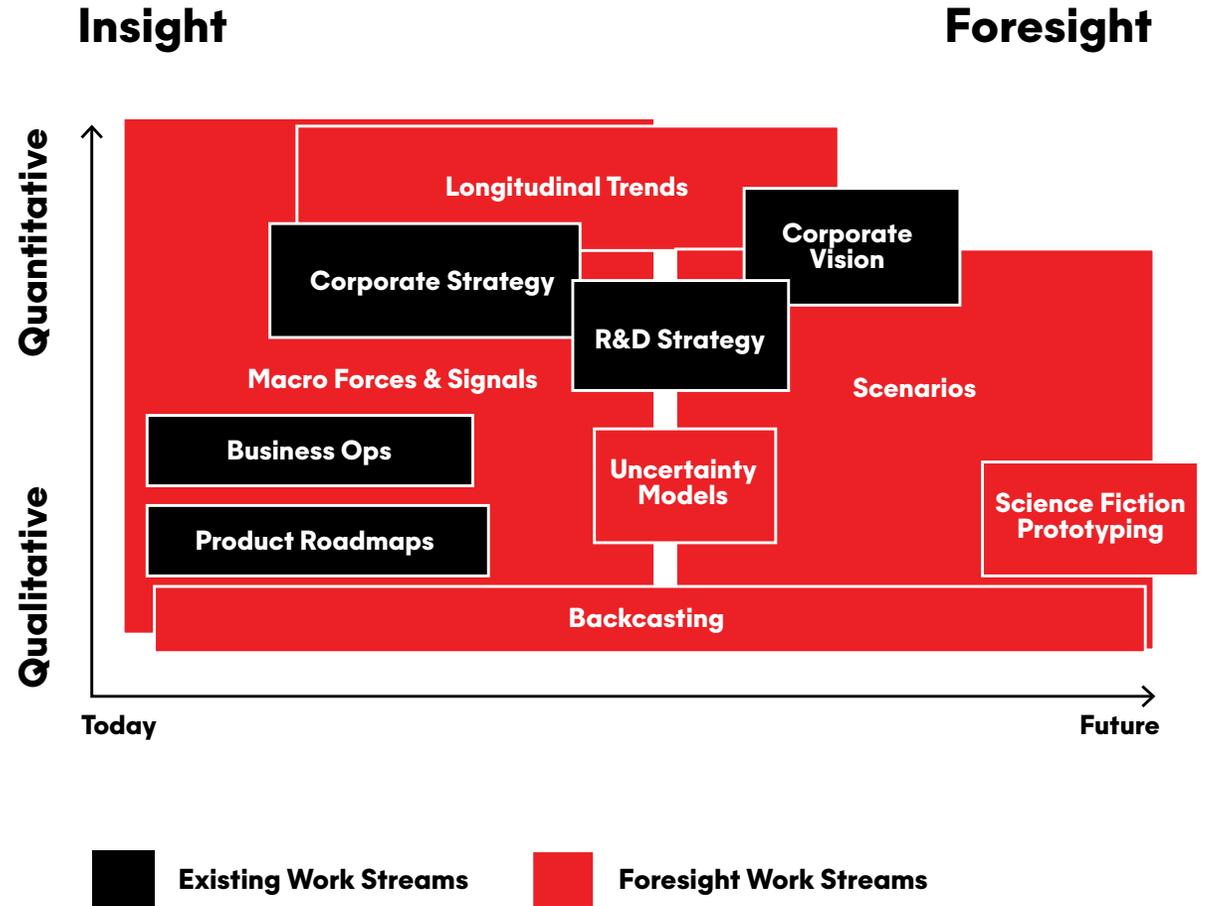
Companies with a dedicated strategic foresight methodology and resources outgrew their competitors 200%.

25% Improvement

Companies say that strategic foresight improves business objectives and planning, helps define new markets, and builds flexible mindsets among executives, even in times of deep uncertainty.

Foresight

Foresight Complements Existing Work Streams



Team



AMY WEBB

CEO

awebb@futuretodayinstitute.com

Founder of the Future Today Institute, Amy Webb pioneered a data-driven, technology-led foresight methodology practiced by FTI and used within hundreds of organizations worldwide. She leads FTI's technology research initiatives on artificial intelligence, synthetic biology and genetic engineering, next-generation networks, and quantum technologies. Webb is a professor of strategic foresight at the New York University Stern School of Business, where she developed and teaches the MBA course on strategic foresight. She is a Visiting Fellow at Oxford University's Saïd School of Business, a Nonresident Senior Fellow in the Atlantic Council's GeoTech Center and a Fellow in the United States-Japan Leadership Program. She was elected a life member to the Council on Foreign Relations. Webb was named by Forbes as one of the five women changing the world, listed as the BBC's 100 Women of 2020, ranked on the Thinkers50 list of the 50 most influential management thinkers globally. A lifelong science fiction fan, she collaborates closely with writers and producers on films, TV shows and commercials about science, technology and the future. Her newest book, *The Genesis Machine*, explores the futures of synthetic biology and the bioeconomy.



MELANIE SUBIN

Director of Consulting

msubin@futuretodayinstitute.com

Melanie Subin is the Director of Consulting for Future Today Institute, with concentrations in the metaverse and decentralization and expertise in risk, consumer insights, and scenario planning. She co-teaches the MBA course in strategic foresight at the New York University Stern School of Business. Previously, Melanie served in insights and foresight leadership roles at Travelers Insurance. She has specializations in strategic management, insights development, and financial services. Melanie holds a Bachelor of Science in Finance from Central Connecticut State University and a Certification in FinTech from the Massachusetts Institute of Technology.

Team



JENNIFER KARPPINEN

Senior Foresight Associate
jkarppinen@futuretodayinstitute.com

Jennifer Karppinen is a Senior Foresight Associate at the Future Today Institute where she helps leaders navigate uncertainty at the intersection of technology and business. She has extensive experience advising clients in retail, energy, media/telecommunications, health care, and financial services. Jennifer holds an MBA from Emory University's Goizueta Business School and a BS in Mechanical Engineering from North Carolina State University.



NICK BARTLETT

Senior Foresight Associate
nbartlett@futuretodayinstitute.com

Nick Bartlett is a Senior Foresight Associate at the Future Today Institute and a coach in the strategic foresight MBA course at the NYU Stern School of Business. Prior to FTI, he held positions in corporate strategy and insights generation roles, serving as a partner to senior leadership at multiple Fortune 100 financial services companies. Nick specializes in insights development, framework design, corporate innovation, strategic management, and financial services. He holds an MBA and a bachelor's degree in Public Relations from Quinnipiac University.



RYAN HOGAN

Foresight Associate
rhogan@futuretodayinstitute.com

Ryan Hogan is a Foresight Associate at the Future Today Institute where he leads research in recognition, space, and energy. Additionally, he is a coach in the strategic foresight MBA course at the NYU Stern School of Business. He has worked with clients from traditional publishing to large-scale internet platforms, to leading-edge programs in decentralization and space futures. He has been featured in the Journal of Futures Studies, IEEE, and was a 2015 team finalist for Fastco's Innovation by Design Awards. He holds an MBA in Strategic Foresight from California College of the Arts and a BA in Art and Philosophy from Freed-Hardeman University.



CHRISTINA VON MESSLING

Foresight Associate
cvmessling@futuretodayinstitute.com

Christina von Messling is a Foresight Associate at the Future Today Institute. She brings to the work extensive experience in technology innovation consulting for Fortune 100 companies and an in-depth background in digital media and creative direction. She holds a Masters in Law from the Freie Universität in Berlin and ranked in the top ten percent of the country. Christina is a coach in the strategic foresight MBA course at the NYU Stern School of Business. She is a published photographer and has extensive training in the design thinking methodology. She is specifically interested in the futures of human societies and culture.

Team



MARC PALATUCCI

Senior Foresight Affiliate
mpalatucci@futuretodayinstitute.com

Marc Palatucci is a Senior Affiliate at the Future Today Institute, with research specializations in the metaverse and new realities (AR/ VR/ XR, DR), digital fashion, retail and e-commerce. He co-teaches the MBA course in strategic foresight at the NYU Stern School of Business. Palatucci serves on the World Health Organization's Learning Strategy Advisory Group and is a Senior Deputy to the World Economic Forum's Platform for Shaping the Future of Media, Entertainment and Culture. He holds an MBA in Emerging Technology from New York University's Stern School of Business and a BA in Linguistics and Languages from NYU's Gallatin School.



ELENA GIRALT

Foresight Affiliate
egiralt@futuretodayinstitute.com

Elena Giralt is a Foresight Affiliate at the Future Today Institute, where she leads research in blockchain, cryptocurrencies, decentralized media and technology. She holds an MBA from New York University's Stern School of Business and a BA/BS in Political Science, French and Middle Eastern Studies from Santa Clara University.



SAM GUZIK

Foresight Affiliate
sguzik@futuretodayinstitute.com

Sam Guzik is a Foresight Affiliate specializing in technology, digital products, subscription products, and newsroom tools. His career includes a broad range of experience that includes product management, strategic foresight, scenario forecasting, audience engagement and leadership in legacy news organizations. Passionate about building a sustainable future for local news, Guzik has demonstrated results creating innovative, engaging and impactful journalism — and business models to support that work. Guzik is a graduate of Washington University in St. Louis, Columbia University Graduate School of Journalism and the NYU Stern School of Business.



KRISTOFER "KRIFFY" PEREZ

Foresight Affiliate
kperez@futuretodayinstitute.com

Kristofer "Kriffy" Perez specializes in fintech, banking, financial services, transportation, product innovation, and long-term strategy. Previously as a Director of North American Product Innovation and Design at Visa, he led product and design teams to deliver new product solutions and best-in-class customer-centric experiences to market-leading financial institutions. Kriffy has also worked for MasterCard Advisors, the Boston Consulting Group, IBM, and co-founded a paytech startup. Kriffy has played an integral role in more than 120 strategic projects across 8 countries and has filed 15+ patents.

Team



EMILY CAUFIELD

Creative Director
 ecaufield@futuretodayinstitute.com

Emily Caufield has served as Creative Director for the Future Today Institute for the past decade. She uses her graphic design skills to communicate complex ideas, visualize data, and develop frameworks for use in strategic foresight and futures activities.



ERICA GRAU

Designer
 egrau@futuretodayinstitute.com

Erica Grau is a freelance graphic designer with over a decade of experience. She grew up in Atlanta, Georgia where she graduated with a degree in advertising from The University of Georgia and then furthered her education at The Creative Circus in graphic design. She then moved to New York City where she has worked with many clients including The United Nations, The Bronx Zoo, Weight Watchers and many more. From print to digital design, she enjoys working on a variety of different types of projects to continue growing her skillset.



JENNIFER ELSEVER

Editorial Director
 jalsever@futuretodayinstitute.com

Jennifer Alsever led editorial production for the 2022 FTI Tech Trends Report. She has been a journalist for more than two decades covering tech, biotech, startups and business for such publications as Fortune Magazine, the Wall Street Journal, the New York Times, Wired and Fast Company. A popular young adult fiction writer, Alsever has won multiple YA awards for her Trinity Forest Series.



CHERYL COONEY

Director of Operations
 ccooney@futuretodayinstitute.com

For over a decade, Cheryl Cooney has served as the Future Today Institute's director of operations, where she manages workflows, planning and logistics. Cooney is a published poet, with works appearing in American and Australian anthologies.

Team



MEL BLAKE

Business Development
mblake@futuretodayinstitute.com

Mel Blake handles commercial development and client relations for FTI. He was formerly founder and managing director of Monitor Talent, a speaker agency he founded at the Monitor Group, a global consulting firm. He is a board member of The Yale Center for Customer Insights. He holds an MBA from the Yale School of Management and a BA in Economics from Wesleyan University.

TOM FOSTER

Editor

SARAH JOHNSON

Editor

Trends in Action

The Future Today Institute Supports Executive Leaders and Their Teams

The Future Today Institute works closely with executive leadership and management teams to transform their strategic thinking on the future.

We leverage these and other trends and use **applied foresight** to develop **deep** (20+ years), **long-range** (10+ years) and **near-term** (2+ years) scenarios and strategic plans.

FTI's advisory services include signal mapping, trend identification, scenario development, risk modeling, visioning, and strategic planning.

About the Future Today Institute

Founded in 2006, the Future Today Institute researches, models, and prototypes future risk and opportunity. As the leading strategic foresight and futures management consultants to executive leadership teams worldwide, FTI's data-driven applied research reveals trends and calculates how they will disrupt business, government, and society.

Together with our clients and partners, FTI is helping leaders achieve their preferred futures. Our pioneering, data-driven forecasting methodology and tools empower leaders to make better decisions about the future, today.

Contact Us

hello@futuretodayinstitute.com
267-342-4300
www.futuretodayinstitute.com

Social

Twitter
[@FTI](https://twitter.com/FTI)

LinkedIn
[@Future-Today-Institute](https://www.linkedin.com/company/future-today-institute)

Facebook
[@FutureTodayInstitute](https://www.facebook.com/FutureTodayInstitute)

Instagram
[@futuretodayinstitute](https://www.instagram.com/futuretodayinstitute)

Disclaimer

The views expressed herein are the authors' own and are not representative of the greater organizations in which they have been employed. The names of companies, services, and products mentioned in this report are not necessarily intended as endorsements by the Future Today Institute or this report's authors.

The Future Today Institute's 2022 Tech Trends Report relies on data, analysis, and modeling from a number of sources, which includes sources within public and private companies, securities filings, patents, academic research, government agencies, market research firms, conference presentations and papers, and news media stories. Additionally, this report draws from the Future Today Institute's previous EMT Trends Reports, FTI Trend Reports, and newsletters.

FTI's reports are occasionally updated on the FTI website.

FTI advises hundreds of companies and organizations, some of which are referenced in this report. FTI does not own any equity position in any of the entities listed in this presentation.

Any trademarks or service marks used in this report are the marks of their respective owners, who do not endorse the statements in this report. All rights in marks are reserved by their respective owners. We disclaim any and all warranties, expressed or implied, with respect to this report.

Using and Sharing the Material in this Report



We invite you to use, share, and build upon the material in our 15th annual Future Today Institute Tech Trends Report. We are making it freely available to the public. This work is licensed under a Creative Commons CC BY-NC-ND 4.0 International License.

You are free to:

Share

Copy and redistribute the material in your organizations and classrooms.

Under the following terms:

Attribution

You must give appropriate credit to the Future Today Institute, provide a link to this Creative Commons license, and indicate if any changes were made. You may do so in any reasonable manner, but not in any way that suggests that the Future Today Institute endorses you or your use.

NonCommercial

You may not, under any circumstance, use the material for commercial purposes.

No Derivatives

If you remix, transform, or build upon the material, you may not distribute the modified material.

You are prohibited from:

Commercial Sharing

Don't copy and redistribute this material in any medium or format for commercial purposes, including any personal/corporate marketing and client services.

Representing This Work As Your Own

Do not represent any part of this material as your own without giving credit to the Future Today Institute.

Changing This Material

If you remix, transform, or build upon the material, you may not distribute the modified material.

Additional Restrictions

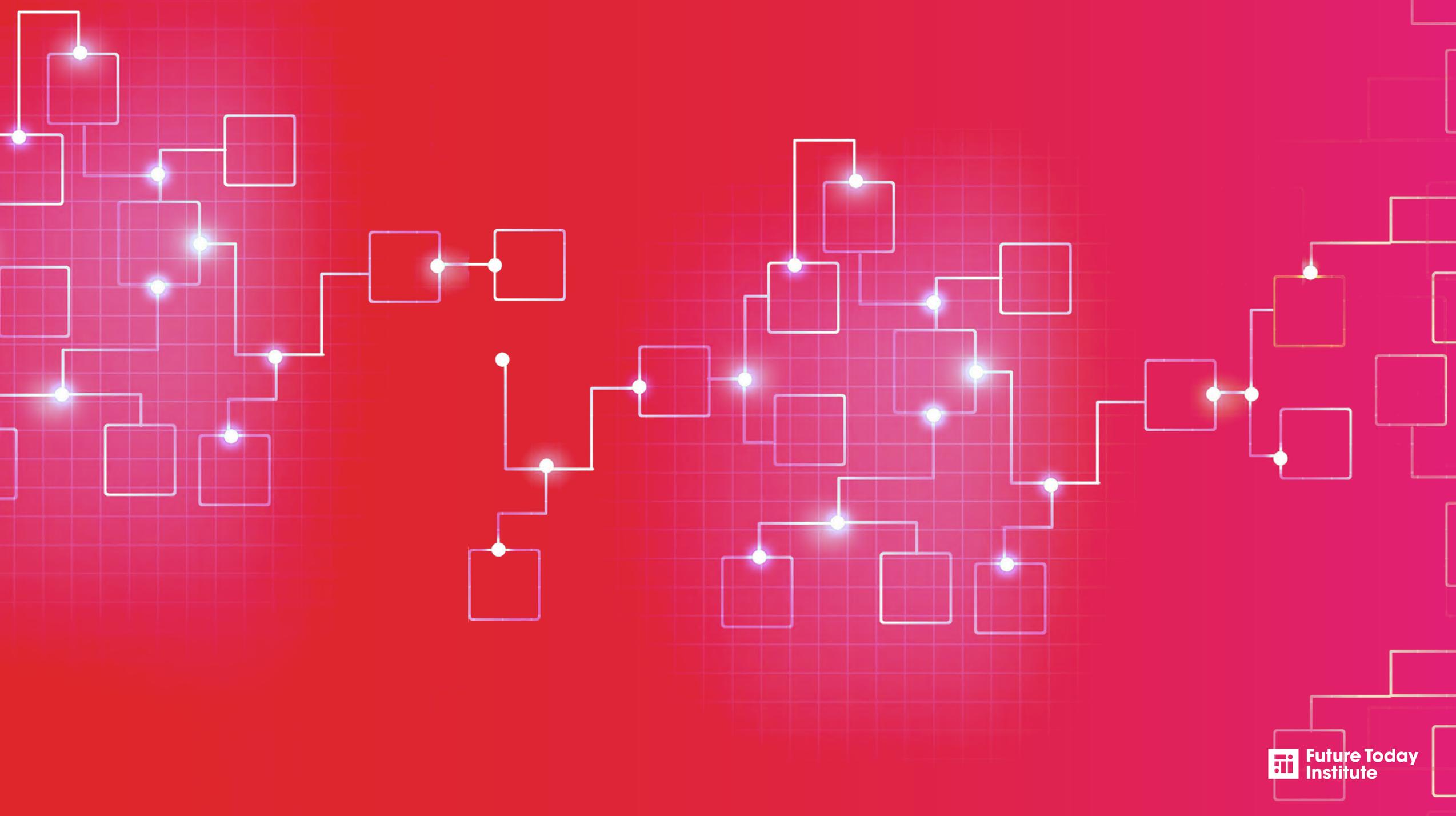
You may not apply legal terms or technological measures that legally restrict others from doing anything this license permits.



Imagining yourself in the future is a radical act.

— Amy Webb, CEO, Future Today Institute





Artificial Intelligence

Artificial Intelligence trends in business, government, research, talent, creative fields and society.

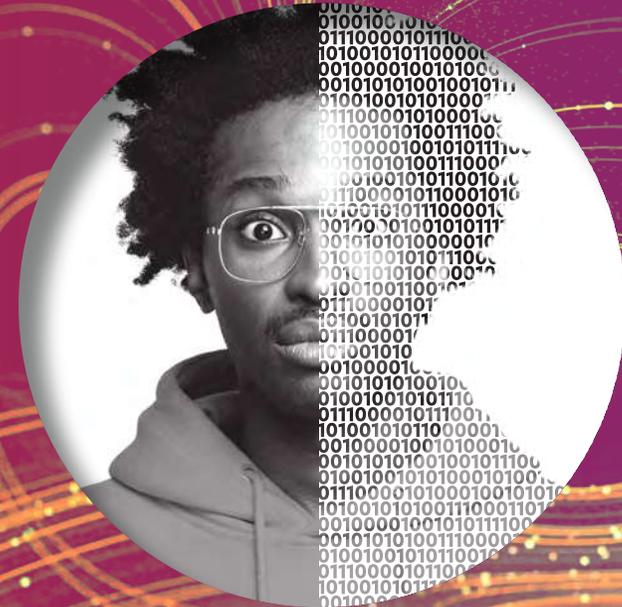


Table of Contents

40 Key Insights	56 Robotic Picking and Replenishing	67 Protein Folding	74 Ethics Guidelines for Tech Contractors	87 Corporate AI Labs
42 State of AI in 2022	56 100-Year Software	67 AI Speeds Scientific Discovery	75 The Mil-Tech Industrial Complex	88 Applied AI for HR
43 Key Terms	57 Consumer Trends	67 AI-First Drug Discovery	76 China Spotlight	89 Scenario: Say NO to the Dress!
45 AI: Techniques and Influential Models	58 Detecting Emotion	68 AI Improves Patient Outcomes	77 Expanding market	90 Society Trends
47 Techniques to Watch in 2022	58 Simulating Empathy and Emotion	68 Deep Learning Applied to Medical Imaging	77 China's AI ethics	92 Expanding Use of Facial Recognition Systems
49 Models to Watch in 2022	58 Theory of Mind Models	68 Self-Driving Microscopes	77 Cracking down on Big Tech	92 Increased Used of Ambient Surveillance
51 Enterprise Trends	59 Spotting Fakes	69 NLP Algorithms Detect Virus Mutations	77 Strategic panopticon	92 Scattershot Approach to U.S. Regulations
53 Low-Code or No-Code Machine Learning	59 Consumer-grade AI Applications	69 Using AI to Improve Talk Therapy	78 Risk profile	92 Consolidation in AI's Ecosystem
53 Web-Scale Content Analysis	59 Ubiquitous Digital Assistants Get Smarter	69 Dream Communication	79 China's supremacy	93 AI Alignment
53 Serverless Computing	60 Deepfakes for Fun	69 Thought Detection	80 Research Trends	93 Ethics Clash
53 AI in the Cloud	60 Personal Digital Twins	70 Scenario: The Real Future of AI	83 Supersized AI Models	93 AI Still Has a Bias Problem
54 AI at the Edge	61 Creative Field Trends	71 Geopolitics and Military Trends	83 Unified Learning Processes	93 Deepfaking Trust
54 Auto-Complete for Everything	63 AI-Assisted Invention	72 The European Approach to Regulating AI	83 Textless NLP	94 Problematic Training Data
54 Advanced AI Chipsets	63 Assisted Creativity	72 AI Nationalism	84 Closed-Source Code	94 Algorithms Targeting Vulnerable Populations
54 Processing-in-Memory Technology	63 Generative Algorithms for Content Production	72 National AI Strategies	84 Framework Consolidation	94 AI Intentionally Hiding Data
55 The Rise of MLOps	64 Neural Rendering	73 AI as Critical Infrastructure	84 Lowering the Cost of Training Models	95 Undocumented AI Accidents
55 Robotic Process Automation (RPA)	64 Generating Virtual Environments from Short Videos	73 Nation-based Guardrails and Regulations	84 Surpassing NLP Benchmarks	95 Prioritizing Trust
55 Predicting Workplace Injuries	64 Automated Versioning	73 Regulating Deepfakes	84 No Retraining Required	97 Application
55 Predicting Systems and Site Failures	64 Automatic Voice Cloning and Dubbing	73 Making AI Explain Itself	84 Proliferation of Franken-Algorithms	98 Key Questions
55 Liability Insurance for AI	65 Automatic Ambient Noise Dubbing	73 New Strategic Technical Alliances	85 AI Summarizing Itself	99 Selected Sources
55 Manipulating AI Systems for Competitive Advantage	65 Ambient Interfaces	74 AI to Guide Air Strikes	86 Talent Trends	
56 AI Marketplaces	66 Health, Medicine and Science Trends	74 Algorithmic Warfighting	87 Demand for AI Talent Growing Fast	
56 AI-Powered InsureTech			87 AI Upskilling	
			87 AI Brain Drain	

Key Insights

- * During the next decade, artificial intelligence will reshape the knowledge economy, automating some tasks currently performed by people and augmenting others.
- * Companies are looking to upskill their workforce in machine learning and the basics of AI.
- * Machine learning is transitioning, as new platforms allow businesses to leverage the power of AI to build applications without the need to know specific code.
- * Deep neural networks are now listed among the 10 fastest growing technologies in the U.S., as indicated by patent applications.
- * In some U.S. states, facial recognition without consent is now illegal. But there are no laws against emotional recognition.
- * During the 2022 Super Bowl, several ads made use of deepfakes, which are becoming cheaper and easier to create.
- * AI is being deployed to speed scientific discovery.
- * Three research teams from Microsoft, Google, and Baidu have surpassed human baselines on SuperGLUE natural language processing (NLP) tasks.
- * Deep neural networks are being used to analyze emotional states using wireless signals. Scientists are warning that advertisers could begin to alter and drive purchasing behavior through sleep and dream hacking.
- * Strict new regulations in China and the EU could challenge the development of AI.
- * Governments are instituting new restrictions on mergers and acquisitions and investment activity to ensure that AI developed by companies does not aid foreign adversaries.
- * Several governments are attempting to regulate deepfake technology. Bills to regulate or prohibit the use of deepfakes have been introduced in California, Texas, and Massachusetts, and a number of federal bills are being discussed.
- * The U.S. military has started using AI to guide its airstrikes, deploying algorithms to a live operational kill chain.
- * Within the next decade, China plans to meet two crucial milestones: By 2027, its People's Liberation Army will have a modern-ready force, and by 2030 the Chinese Communist Party expects to have outpaced the U.S. in AI and become the singular dominant force.
- * China is forging ahead on its own NLP models. Two massive models developed specifically for the Chinese language market, Wu Dao 2.0 and M6, will start to shape the future of AI development.
- * Our future wars will be fought in code, using data and algorithms as powerful weapons.
- * We will soon reach a point when we will no longer be able to tell if a dataset has been tampered with, either intentionally or accidentally.
- * A new type of software could be viable for 100 years, making use of AI to dynamically adapt to changes in environments and resources.



Artificial Intelligence

State of AI in 2022

Artificial intelligence represents the third era of computing, generally defined as the ability for a machine to perform cognitive functions as well as or better than humans. Such functions include perception, learning, reasoning, problem-solving, contextual understanding, making inferences and predictions, and exercising creativity.

AI is now used across most industries. It solves business problems, detects fraud, improves crop yields, manages supply chains, recommends products, and even assists designers and writers in their work. AI can predict call volume in customer service centers and recommend staffing levels; it also predicts the emotional state and behavior of the person calling to help companies anticipate desirable solutions. AI automates the process for drug discovery, which ultimately led to faster COVID-19

vaccine candidates. Because AI is so broad, we have identified different themes to track; however, because AI is now so deeply intertwined with every aspect of life, you will find AI mentioned in other trends throughout all 13 volumes of the Future Today Institute's 2022 report.

Since publishing our first Tech Trends report 15 years ago, we have included and expanded our coverage on artificial intelligence. What began as several pages of insights is now a dedicated, stand-alone report with more than 100 trends to monitor. We believe AI is a force multiplier because it both enables technology and is powering the evolution of business, government, and society. AI is already transforming most economic sectors, but we anticipate deeper impacts across health care, biotech, cloud computing, fintech, consumer electronics, and military applications in 2022.



Key Terms

Machine Learning (ML)

Machine learning uses data to make predictions and recommendations on how to achieve stated goals. AI pioneer Arthur Samuel popularized the idea of machine learning in 1959, explaining how computers could learn without being explicitly programmed. This would mean developing an algorithm that could someday extract patterns from datasets and use those patterns to predict and make real-time decisions automatically. It took many years for reality to catch up with Samuel's idea, but today machine learning is a primary driver of the growth in AI.

There are different types of machine learning including supervised, unsupervised, and reinforcement.

Supervised learning

A model attempts to transform one type of data into another type using labeled examples. Supervised learning is used

when teams know how to classify the input data and what they are trying to predict but can get accurate results much more quickly by relying on an algorithm rather than a human. This is the most common form of ML used today. For example: Understanding what product features would most likely drive new purchases is a business use case for supervised learning.

Unsupervised learning

Data is provided to a model without specific output parameters, and it tries to learn the dataset's structure without any designated labels. For example, if a researcher doesn't know quite what to do with a large dataset, an unsupervised learning model could determine patterns, classify data, and make recommendations without a human supervisor. Unsupervised learning has been used during the pandemic to find patterns in how COVID-19 is spreading throughout communities.

Reinforcement learning (RL)

A system performs a task by repeatedly running calculations as it attempts to accomplish a stated goal. It's a trial-and-error process, where rewards or penalties are earned in response to the system's performance toward achieving the stated goal. RL is used when there isn't enough training data, when the researcher is trying to learn about an environment (such as a complex financial portfolio), or when the researcher needs to find greater levels of optimization. It has a tremendous number of business use cases, ranging from real-time dynamic pricing models to high frequency trading algorithms to the systems that run self-driving cars.

Deep Learning (DL)

Deep learning is a relatively new branch of machine learning. Programmers use special deep learning algorithms alongside an enormous corpus of data—typically many terabytes of text, images,

videos, speech, and the like. Often, these systems are trained to learn on their own, and they can sort through a variety of unstructured data, whether it's making sense of typed text in documents or audio clips or video. In practical terms, deep learning's emergence means that more and more human processes will be automated, including the writing of software, which computers will soon start to do on their own. For example, once a system learns what an object looks like—say, an apple—it can recognize that object in all other images, even if it has only a partial view.

There are different types of deep learning architectures. The most common types include convolutional neural networks, recurrent neural networks, transformer neural networks, and generative adversarial networks (GANs).

■ Convolutional neural network (CNN)

A CNN is multilayered, with a convolutional layer, a pooling layer, and a fully

connected layer. Each one performs a different task using the data. The output is classification. If a researcher has 10,000 images and needs to extract data—to recognize particular faces, for instance—the CNN would run until information could be inferred. In business, CNNs are used for recognition such as anomalies in medical imaging, faulty products on a production line, blight on crops.

■ Recurrent neural networks (RNNs)

These multilayered neural networks move and store information between input, hidden, and output layers. They are good at modeling sequence data for predictions. In business, they are used anytime the sequence of data matters, such as speech recognition and language translation. RNNs are used in digital assistants, to create captions for images and to generate narrative reports using structured data (sports, financial).

Key Terms



This year is the 10th anniversary of an important milestone in AI. In 2012, a neural network taught itself to recognize a cat. It required 16,000 computer processors and 10 million YouTube videos.

■ Transformer neural networks (TNNs)

A transformer is a component whose purpose is to process sequential data, such as natural language or genome sequences. Transformers rely on “attention” (the mathematical description of how things relate to, complement or modify each other) in translating sequences. A transformer neural network is the unique architecture that enables systems to learn from context and to generate new information. TNNs are complementary to CNNs and RNNs, the two most common neural network architectures used in deep learning.

■ Generative adversarial networks (GANs)

As unsupervised deep learning systems, GANs are composed of two competing neural networks—a generator and a discriminator—that are trained on the

same data, such as images of people. The networks compete against each other to perform a task—identifying the correct person—which results in optimizing overall performance. GANs are useful when researchers don’t have enough data to train an algorithmic model. They are also used to create new, synthetic data. Deepfakes, which have become popular in the past year, are generated using GANs. In design, GANs are tremendously useful: They can produce thousands of designs and recommend the best ones based on desired parameters. They can generate and modulate voices, faces, even gestures. Researchers from Nvidia, Massachusetts General Hospital, BWH Center for Clinical Data Science, and the Mayo Clinic collaborated on a GAN that generates synthetic MRIs showing cancerous tumors.

Algorithm

A process describing how to solve a specific problem or how to complete a particular task.

Computer Vision

Processes that give computers the ability to derive meaningful information from digital images (including still and video) and to mimic and manipulate such images.

Model

A program that has been trained on a dataset. Models are generally used for analytical and decision-making tasks, such as making predictions.

Natural Language Processing

Processes that give computers the ability to understand, mimic, and manipulate human language.

Transformer

A type of neural network mechanism that learns what text means when it appears in a particular context. Using “attention,” a transformer looks at an input sequence and determines at each step what other parts of the sequence are important. To date, transformers have mainly been used in natural language processing, image generation and genome sequencing.



00

01

02

03

04

05

06

07

08

09

10

11

12

13

Artificial Intelligence

AI: Techniques & Influential Models

**I may not be real. But for a second there,
I felt pretty alive.**

— Guy, in *Free Guy*

AI: Techniques and Influential Models

Techniques to Watch in 2022

Automated Machine Learning (AutoML)

Some organizations want to move away from traditional machine learning methods, which are time-consuming and difficult and require data scientists, specialists in AI fields, and engineers. AutoML operates differently by matching raw data and models together to reveal the most relevant information. Google, Amazon, and Microsoft include a host of AutoML products within their cloud service offerings.

Continuous Learning

At the moment, deep learning techniques are helping systems learn to solve complex tasks in a way that resembles what humans can do—but those tasks are still specific, such as beating a human at a game. And they require a rigid sequence: Gather data, determine the goal, deploy an algorithm. This process requires humans and can be time-consuming, especially during early

phases when supervised training is required. Continuous learning is more about autonomous and incremental skill building and development, and researchers will continue to push the limits of what's possible in this field.

Federated Learning

Federated learning is a technique that distributes machine learning to the edge. Introduced by Google researchers in 2016, it is a framework that makes it possible for algorithms to use data on devices—such as mobile phones and smart watches—without compromising user privacy. Research in this space has dramatically increased.

General Reinforcement Learning Algorithms

Researchers are developing single algorithms that can learn multiple tasks. DeepMind, the team behind AlphaGo, which learned how to play Go with the skill level of a human grand master,

continues to push its research forward. MuZero mastered multiple games without being told their rules, a “significant step forward in the pursuit of general-purpose algorithms,” according to DeepMind. In a seminal paper, “Reward Is Enough,” published at the end of 2021, DeepMind researchers hypothesized that artificial general intelligence could be achieved through reinforcement learning alone.

Graph Neural Networks

Because we perceive scents using millions of sensory neurons in our brains, and because scents are multifaceted, predicting the way something will smell is incredibly complex. For example, how would you describe the smell of an orange? Sweet? Bright? Grassy? Each descriptor is unique. Classifying smell is tricky because it requires a multi-label system. Graph neural networks (GNNs) constitute a particular type of deep neural network that operates on graphs

as inputs. GNNs are being used to detect smell—to predict odors at a molecular level—and for a wide array of chemical and biological processes. For example, researchers at the Broad Institute used them to discover antibiotic compounds that don't have toxic side effects.

Hybrid Human-Computer Vision

AI isn't yet capable of fully functioning without human assistance. Hybrid intelligence systems combine humans and AI systems to achieve greater accuracy. The U.S. Army Research Laboratory has a system that uses a brain-computer interface armed with computer vision technology and allows a person to rapidly see and sort images within her line of sight. CloudSight, which specializes in image captioning, is working on a hybrid crowdsourced computer vision system. Microsoft researchers have proposed Pandora, a set of hybrid human-machine methods and tools for

understanding system failures. It builds off both human- and system-generated observations to explain malfunctions related to input content and system architecture.

Machine Image Completion

If a computer system has access to enough images—say, millions and millions—it can patch and fill in holes in pictures. This capability has practical applications for professional photographers, as well as for everyone who wants to take a better selfie. Soon, if the foreground of a mountain is out of focus, or if your skin has an unsightly blemish, another version can be swapped in to generate the perfect picture. As such technology becomes commonplace, there will be significant biases and other pitfalls to navigate. For example, image generation algorithms routinely reflect deeply culturally embedded racism and sexism. A few years

AI: Techniques and Influential Models

Techniques to Watch in 2022

ago, if you typed “CEO” into Google Images, the first result of a woman was CEO Barbie. In an experiment, researchers at Carnegie Mellon University trained a system to autocomplete images of men and women cropped below the neck. In pictures of men, the system auto-completed him wearing a suit. The system auto-completed women—including U.S. Rep. Alexandria Ocasio-Cortez (D-N.Y.)—wearing a low-cut top or bikini 53% of the time.

Model-free Approaches to RL

Dreamer is a reinforcement learning (RL) agent that uses a world model to learn long-sighted predictions, employing backpropagation through model predictions. It can create models from raw images and learn from thousands of predicted sequences in parallel using a graphics processing unit (GPU). This new approach solves long-horizon tasks using an imagined world.

Predictive Models Using Incomplete Data

Computer vision systems are getting smarter. Neural networks can predict geometry from a single color image. In 2019, the DeepMind team developed a generative adversarial network (GAN) that creates videos from images. For example: Imagine a photo of a person holding a basketball. Based on his posture, face, and other data within the picture, the GAN figures out what likely happened next and generates a video clip of the action. Earlier, researchers at MIT’s Computer Science and Artificial Intelligence Laboratory (CSAIL) trained computers to predict what humans would do next using YouTube videos and TV shows such as “The Office” and “Desperate Housewives.” CSAIL’s system predicts whether two people are likely to hug, kiss, shake hands, or slap a high five. SinGAN is an unconditional generative scheme that can manipulate and enhance images—sketch a mountain,

and it will produce a realistic-looking synthetic photograph. This research will someday enable robots to more easily navigate human environments—and to interact with us humans by taking cues from our body language. Retail, manufacturing, and education settings could be especially relevant.

Neuro-Symbolic AI

The development of AI has been on two conceptual tracks since the 1950s: symbolic (machines that use a base of knowledge and rules that represent concepts) and non-symbolic (machines that use raw data to create their own patterns and representations of concepts). Classic AI is the former, because it more closely represents how we understand human thought—and the original intent was to teach machines to think like us. Researchers are working on new ways to combine both learning and logic using neural networks, which would understand data through symbols rather

than always relying on human programmers to sort, tag, and catalog data for them. Symbolic algorithms will aid the process, which should eventually lead to robust systems that don’t always require a human for training.

Real-time Machine Learning (RTML)

One big challenge in AI is building machines that can proactively collect and interpret data, spot patterns and incorporate context, and ultimately learn in real time. New research into RTML shows that it’s possible to use a continual flow of data and adjust models in real time. This signals a big change in how data moves, and in how we retrieve information. The National Science Foundation launched a \$10 million grant program to catalyze research in this area, although all of the big tech companies are working closely to advance RTML too.

Vokenization

Models like GPT-3 are trained on syntax and grammar, not creativity or common sense. So researchers at the University of North Carolina–Chapel Hill are combining language models with computer vision. Humans learn in a multilayered, multidimensional way, so a new technique called vokenization extrapolates language-only data by contextually mapping language “tokens,” or the words used to train language models, to related images, or “vokens.” For example, auto-generated image captions often can’t infer context. Vokenization would enable machines not just to recognize objects but to really “see” what’s in them.

AI: Techniques and Influential Models

Models to Watch in 2022



DALL-E is a model that generates images based on a prompt. Researchers inputted the prompts “an armchair in the shape of an avocado” and “an armchair imitating an avocado,” and DALL-E returned a number of options.

DALL-E

Developed by OpenAI last year, DALL-E is a model trained to manipulate visual concepts through language. It begins with a prompt that’s written in natural language and then generates a set of images showing its interpretation of the intended meaning. Named for Spanish surrealist artist Salvador Dali and Pixar robot WALL-E, the model relies on zero-shot capabilities, meaning that it does not need examples to perform generative tasks. In an early example, researchers gave DALL-E the prompt “an armchair in the shape of an avocado,” and it returned a bevy of options ranging from a line drawing to an image of a chair that looks like something you’d see in a furniture store catalog.

GPT-3

GPT-3 is an enormous AI that generates human-like language. Created by Ope-

nAI, the system is capable of generating text that is now indistinguishable from human writing. In fact, we used GPT-3 to write one of the scenarios in this volume and only edited it lightly for length. GPT-3 was pitted against college students in an essay writing contest, and the anonymized papers were graded by professors. It earned mostly B’s—the same as human students. But the AI has demonstrated a strong anti-Muslim bias. Researchers from Stanford University and McMaster University probed the neural network on tasks including prompt completion, analogical reasoning, and story generation. They found that a Muslim-violence bias appears consistently and creatively in many use cases of the model. It’s yet another example of how bias creeps into our automated systems. Left unchecked, it will cause problems throughout society as AI matures.

Google’s LaMDA and MUM

At last year’s I/O conference, CEO Sundar Pichai demonstrated a model capable of managing open-ended conversations. That system, LaMDA, appeared closer to natural conversation following an infinite number of paths after an initial prompt. Google’s Multitask Unified Model, or MUM, is capable of understanding complex queries during search using natural language (text) and a variety of images. MUM could become the future of search, allowing consumers to speak conversationally—and easily—to discover everything they’re looking for.

Switch Transformer

Last year, Google Brain published an important paper demonstrating a new language model architecture. This natural language processing AI model scales way up to 1.6T parameters while

AI: Techniques and Influential Models

Models to Watch in 2022

reducing training time. Many language models are complex and dense; the breakthrough of the switch transformer is that it reduces computational costs while improving accuracy and power.

Chinese Models: Wu Dao 2.0 and M6

Two models developed specifically for the Chinese language market launched last year: Wu Dao 2.0 and M6. The research team behind Wu Dao compare it to GPT-3 but argue that the network is orders of magnitude larger. Meanwhile, Alibaba's M6 is an efficient model that reduces the cost of computing and—impressively—reduces the carbon footprint typically associated with training models on enormous datasets.

Leading Applicants, 2017–2021

Developing AI systems based on biological models—or deep neural networks—is among the 10 fastest growing technologies in the U.S., as indicated by patent applications.



Source: IFI Claims Patent Services, January 2022 study.



00

01

02

03

04

05

06

07

08

09

10

11

12

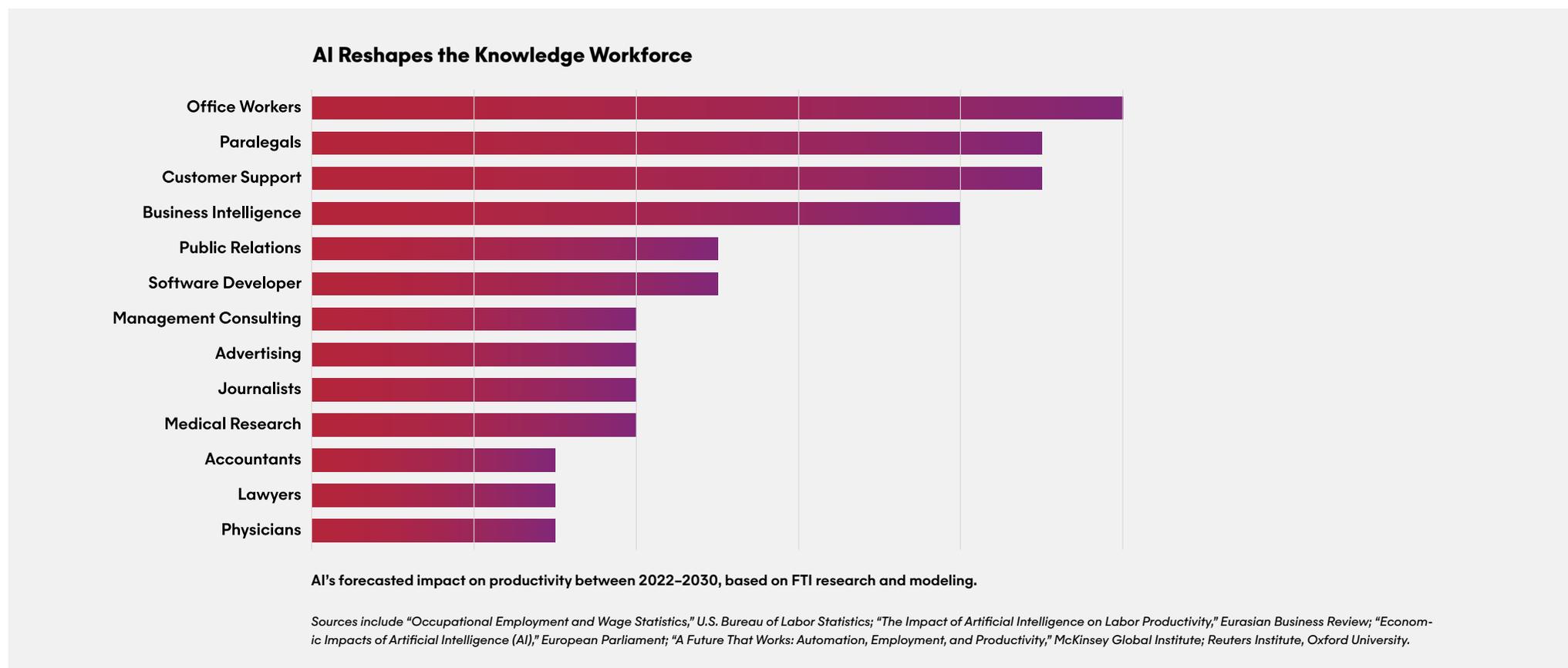
13

Artificial Intelligence

Enterprise

Enterprise Trends

During the next decade, AI will reshape the knowledge economy, automating some tasks currently performed by people and augmenting others. Assistive AI technologies, which include robotic process automation, low-code/no-code ML, the deployment of pretrained transformer models, natural language/conversational search, and completion systems will increase the productivity and output of many knowledge economy professionals.



Enterprise Trends

Input

Output



At Replicate, users can deploy StyleCLIP to give anyone a bowl haircut. Other physical transformations are possible, too, and take only a few seconds.

■ Low-Code or No-Code Machine Learning

Machine learning is transitioning, as new platforms allow businesses to leverage the power of AI to build applications without the need to know specific code. Businesses can turn their unruly datasets into structured data that can be trained, and they can build and deploy models with minimal skills. Create ML is Apple's no-code, drag-and-drop tool that lets users build custom models such as recommendation engines, natural processing systems, and text classifiers. Google Cloud's AutoML includes image classification, object detection, translation, and all sorts of pattern recognition tools to allow developers with limited machine learning expertise to train high-quality models specific to their business needs. MakeML allows developers to create an AI app or solve business problems using computer vision. Applications have included tracking tennis balls during matches and auto-

matically changing the colors of objects (such as flowers or dresses) in images. Last year, Amazon launched a no-code mobile and web app builder for Amazon Web Services (AWS). Microsoft Power Apps is a low-code application development environment on Azure.

■ Web-Scale Content Analysis

Mining very large, unstructured datasets is now easier thanks to advanced natural language processing collection and classification. Trained to recognize keywords, special algorithms can rapidly sort, classify, and tag information to detect patterns. For example, a model trained to search for hate speech can detect bad actors in social networks. Machine translation generates training data for financial crime classification; last year, it reduced the amount of time needed for classification from 20 weeks (human analysts working alone) to two weeks.

■ Serverless Computing

Hyperscalers like AWS, Alibaba Cloud, Microsoft's Azure, Google Cloud, and Baidu Cloud are rolling out new offerings and packages for developers with the goal of making it easier and more affordable for a wide swath of AI startups to launch their ideas into the marketplace. AWS Lambda lets teams run code for virtually any type of application or back-end service—without provisioning or managing servers or hands-on administration. The Azure Functions architecture supports myriad programming languages, scales on demand, and charges only for active compute time. Some engineers worry that such serverless systems require them to surrender too much control.

■ AI in the Cloud

Corporate leaders within the AI ecosystem have been racing to capture AI cloudshare—and to become the most

Enterprise Trends

trusted provider of AI on remote servers. Enterprise customers are likely to stick with their initial vendor, because as machine learning systems get better over time, the more data they amass. For that reason, the competition is furious, even though it's still early. In the West, the field is led by Amazon, Microsoft, and Google, followed by companies including Apple, IBM, Salesforce, SAP, and Oracle. In Asian markets, Alibaba and Baidu dominate the AI cloud, although in January 2020, telecom equipment and smartphone maker Huawei announced a management change to focus on what it calls a “full-stack cloud platform.” It's a \$250 billion industry and quickly growing.

■ AI at the Edge

AI-driven processing and decision-making that occurs closer to the source of data generation, as opposed to in the cloud, is a technique known as edge

computing. The Internet of Things and its billions of devices, combined with 5G networking and increased computing power, has made large-scale AI at the edge possible. Processing data directly on devices will be important in the future for health care, automotive, and manufacturing applications because it's potentially faster and safer. Apple spent \$200 million to acquire Xnor.ai, a Seattle-based AI startup focused on low-power machine learning software and hardware. Microsoft offers a comprehensive toolkit called Azure IoT Edge that allows AI workloads to be moved to the edge: Businesses can deploy complex event processing, machine learning, image recognition, and other high value AI without writing it in-house.

Anyone is able to create AI modules and make them available to the community for use through the Azure Marketplace.

■ Auto-Complete for Everything

Google's AI-based autocomplete technology is finding new applications. In Gmail, the Smart Reply feature checks grammar and makes suggestions; in Android, it automatically generates responses to text messages. It now auto-completes formulas in Sheets, providing context-aware predictions—and querying datasets using natural language. New features will be rolled out in Maps, which now auto-suggests eco-friendly routes and ways to save on fuel consumption. Auto-complete offers convenience for consumers, but as these AI capabilities are rolled into business applications, they could result in new productivity and efficiencies.

■ Advanced AI Chipsets

Today's neural networks have long required an enormous amount of computing power, take a long time to train, and rely on data centers and computers

that consume hundreds of kilowatts of power. That is all starting to change. Enter the SoC, or “system on a chip.” Big tech companies, including Huawei, Apple, Microsoft, Facebook, Google, IBM, Nvidia, Intel, and Qualcomm, as well as startups Graphcore, Mythic, and Cerebras Systems, are all working on new systems architecture and SoCs—some of which come pretrained. In short, this means that the chips are more readily able to work on AI projects and should promise faster and more secure processing. Projects that might otherwise take weeks could instead be accomplished in a matter of hours. In 2019, Cerebras debuted an AI chip with 1.2 trillion transistors, 400,000 processor cores, 18 gigabytes of SRAM, and interconnects (tiny connection nodes) that can move 100 quadrillion bits per second. That's an astounding amount of components and power—and yet last year, it announced that its next-gen

chip, the Wafer Scale Engine 2 (WSE 2), has 2.6 trillion transistors, 850,000 cores, has 40 gigabytes of on-chip memory and 20 petabytes of memory bandwidth. Amazon's homegrown AI chip AWS Inferentia, is a custom machine learning chip used for high-performance inference predictions—it now powers Alexa's back-end services. The pretrained chips will speed up commercialization and further R&D. But if the various device manufacturers all start creating unique protocols, developers may struggle with too many different frameworks. We anticipate an eventual consolidation, pitting just a few companies—and their SoCs and languages—against one another.

■ Processing-in-Memory Technology

A new approach to memory, which could eventually power the next generations of smartphones and help

Enterprise Trends

usher more smart devices to market, involves breaking some of the current bottlenecks in computing. Processing-in-memory (PIM) integrates a processor with RAM on a single chip, which allows computations to be performed in the memory of a computer. In tests, PIM tech delivers significant performance gain while cutting energy consumption. In late 2021, Samsung, which in addition to phones and consumer appliances is also the world's largest manufacturer of dynamic random-access memory, announced a new PIM-enabled chip that could eventually double the performance of neural nets. This matters to the enterprise because it could bring AI applications to a wider array of devices in the near future.

■ The Rise of MLOps

As machine learning matures and new applied business solutions emerge, developers are shifting their focus from

building models to operating them. Within software, a set of best practices known as DevOps relies on tools, automation, and workflows to reduce complexity so that developers can focus on problems that need to be solved. This approach is now being used in machine learning. Some of the fastest-growing GitHub projects are MLOps, or projects that deal with tooling, infrastructure, and operations. Going forward, MLOps will describe a set of best practices that combines machine learning, traditional DevOps, and data engineering.

■ Robotic Process Automation (RPA)

RPA can automate certain tasks and processes within offices and allow employees to spend time on higher-value work. It's the most commonly deployed AI technique among enterprise companies. In health care and insurance, RPA is used to input and process claims. It

supports call centers and help desks, answering common questions and scheduling services. Amazon uses RPA to sift through résumés and prioritize top candidates. In banking, Blue Prism and Automation Anywhere help staff with repetitive work functions. RPA will eventually augment staff and shift productivity into higher gear.

■ Predicting Workplace Injuries

AI systems are being trained to detect possible workplace injuries. Using computer vision models, Turkey-based Intenseye can detect 40 types of employee health and safety incidents in real time. The company says that it does not capture personally identifiable information from the visual data it processes and that it detected 1.8 million unsafe acts in 2020 and 2021. San Francisco-based Voxel uses computer vision to enable security cameras to automatically detect high-risk activities in real time.

■ Predicting Systems and Site Failures

Computer vision can anticipate and identify failures in physical locations. High-tech factories, airline manufacturers, and construction sites use image recognition systems to monitor projects and automatically warn of problems. This is accomplished by comparing data from the real world to that of a digital twin.

■ Liability Insurance for AI

Who's to blame when machines behave badly? When the machine learning system in Uber's self-driving car failed and killed an Arizona pedestrian, the company was likely not covered under traditional cyber insurance. As businesses rush to build and implement AI products and processes, they must plan ahead for emerging risks. For example, what happens if machine learning makes a company vulnerable to attack-

ers who inject fake training data into a system? What if a health care company's AI misinterprets data and neglects to identify cancer among certain patients? These are the kinds of problems that could put a company at risk of lawsuits. New insurance models will help address these issues. Underwriters are starting to include AI under cyber insurance plans. Specialty insurers such as LaPlaya Insurance now offer insurance for AI applications.

■ Manipulating AI Systems for Competitive Advantage

Amazon, Google, and Facebook have all come under fire in the past few years for manipulating their search systems to prioritize results that are more profitable for their companies. For example, Google has been accused of de-ranking websites and promoting news stories from preferred partners. Late in 2019, researchers found that Amazon had

Enterprise Trends



In Japan, a RightHand Robotics picking robot sorts items.

Image credit: RightHand Robotics.

optimized its search algorithm to boost the visibility of Amazon's own brands. Tweaks to search algorithms have a significant impact on what internet users see, whether that is news, products, or advertising. This resulted in the ongoing antitrust lawsuits filed against the companies.

■ AI Marketplaces

Online hubs to share, buy, and sell models are growing in popularity. AWS hosts its own marketplace, offering models and algorithms for computer vision, speech recognition, and text—and its base of sellers includes Intel, CloudSight, and many others. (Think of AWS Marketplace as an Amazon for algorithms and models.) SingularityNET is an AI marketplace built on a blockchain, where different hosted models are intended to intercommunicate. One application—DeOldify—colorizes old images. There are marketplaces for generalists, like GenesisAI, where devel-

opers can upload their work and receive payment when others pay to access it. Now there are specialized marketplaces for specific use cases: Nuance AI Marketplace developed a single API to connect its algorithms to radiologists at 6,500 health care facilities. Bonseyes is a European-specific marketplace to buy and sell AI tools.

■ AI-Powered InsureTech

Insurance companies are applying AI to assess damage and improve forecasts. The Vehicle Damage Inspection model, which is available on AWS Marketplace, uses a machine learning model to determine what part of a car is damaged. After photos are uploaded, it assesses loss—and dramatically reduces the amount of time required for human appraisers to conduct their analysis. Following catastrophic typhoons and weather events in Japan, local insurance companies are relying on computer vision to assess damage after a natural

disaster. Sampo Japan is using the Tractable AI Estimating system to calculate the approximate repair cost of damaged homes.

■ Robotic Picking and Replenishing

As the global pandemic kept people indoors, consumers increasingly relied on e-commerce to shop. During that time, warehouse workers left their jobs. Enter AI-powered robotic picking, sorting, and packing, which is making up for a dearth of workers as consumers continue to shop online. GXO Logistics, which runs warehouses for Apple and Nike, said that it will adopt robots and automated systems this year, to augment its human workforce. Amazon is experimenting with a suite of new robots to efficiently, and autonomously, move items and boxes around warehouses. Globally, warehouses are expected to invest \$36 billion in automation in 2022, according to research group Interact Analysis.

■ 100-Year Software

Traditional software has a short and unpredictable shelf life compared with other engineering tools. This leads to headaches and costly upgrades, often with downtime. As a result, companies and government agencies attempt to keep pace with the evolution of technology by maintaining systems rather than evolving. Libraries, data formats, and protocols can all become outdated quickly, creating vulnerabilities in critical systems. Since 2015, the Defense Advanced Research Projects Agency (DARPA) has funded research to make software viable for more than 100 years. These systems would use AI to dynamically adapt to changes in environments and resources. They require a novel approach to design, using AI to discover and make visible the application's operations and interactions with other systems.



00

01

02

03

04

05

06

07

08

09

10

11

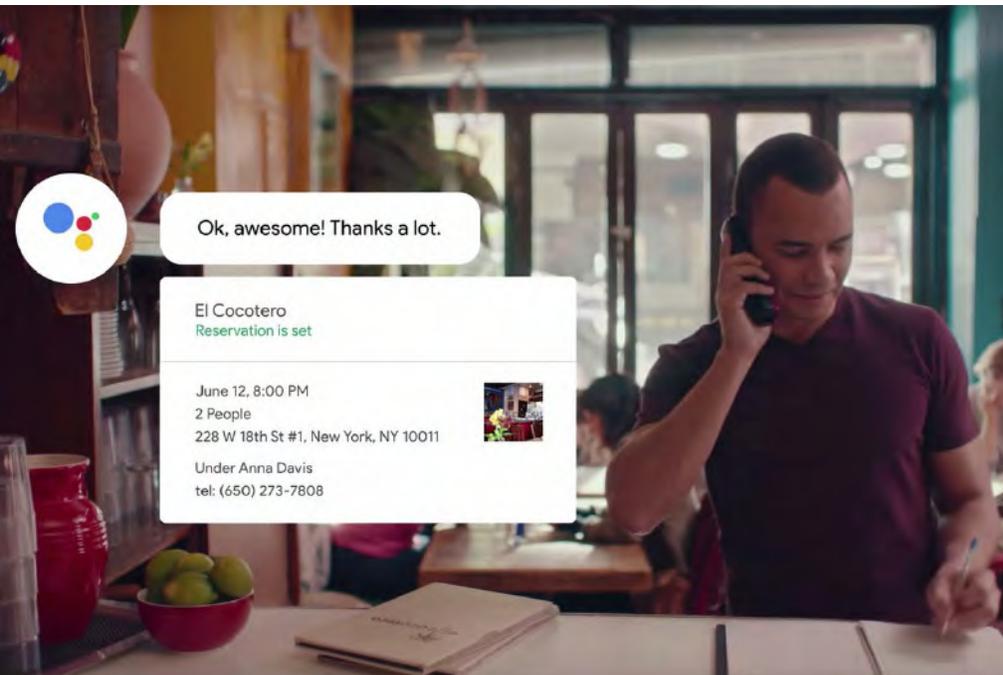
12

13

Artificial Intelligence

Consumer

Consumer Trends



Google Assistant's Duplex automates scheduling, waiting on hold, and other tedious tasks.

■ Detecting Emotion

A new type of neural network can determine how people are feeling. Using radio waves, AI can detect subtle changes in heart rhythms, run a pattern analysis, and predict someone's emotional state in a given moment. A team from Queen Mary University of London used a transmitting radio antenna to bounce radio waves off of test subjects and trained a neural net to detect fear, disgust, joy and relaxation, as people were shown different videos. The system accurately tagged emotional states 71% of the time, which signals new opportunities for health and wellness applications, as well as for job interviews and the government/military intelligence community.

■ Simulating Empathy and Emotion

AI can now measure biomarkers that suggest a person's emotional state, such as agitation, sadness, or giddiness. Precisely detecting human emotion is

challenging, but companies with a large enough dataset are developing accurate models. Amazon's Rekognition API infers someone's emotions using facial recognition and physical appearance. Replika uses AI to evaluate voice and text, and over time it mirrors the user. Affectiva Human Perception AI analyzes complex human states using speech analytics, computer vision, and deep learning. For example, the automotive sector uses Affectiva's technology to detect a driver's emotional state—such as sleepiness or road rage—and make real-time suggestions to improve their driving.

■ Theory of Mind Models

Research teams at Loving AI and Hanson Robotics are teaching machines unconditional love, active listening, and empathy. In the future, machines will convincingly exhibit human emotions such as love, happiness, fear, and sadness. It begs the question: What is

an authentic emotion? Theory of mind refers to the ability to imagine the mental state of others. This has long been considered a trait unique to humans and certain primates. AI researchers are working to train machines to build theory of mind models of their own. This technology could improve existing AI therapy applications such as Woebot, a relational agent for mental health. By designing machines to respond with empathy and concern, these technologies could eventually end up in hospitals, schools, and prisons, providing emotional support robots to patients, students, and inmates. According to health insurer Cigna, the rate of loneliness in the U.S. has doubled in the past 50 years. In our increasingly connected world, people report feeling more isolated. Future governments struggling with a massive mental health crisis, such as South Korea, may turn to emotional support robots to address the issue at scale.

Consumer Trends

■ Spotting Fakes

Researchers recently showed how AI could be used to compose text so good that humans couldn't tell it was machine written. OpenAI demonstrated the many reasons why this was problematic, from mass-generating salacious social media posts and fake reviews to forging documents by world leaders. It turns out that AI can also be used to detect when text was machine generated, even if we humans can't spot the fake. That's because an essay written by AI tends to rely on statistical patterns in text and doesn't have much linguistic variation. Researchers at the MIT-IBM Watson AI Lab and Harvard University developed the Giant Language Model Test Room, which looks for words that are likely to appear in a particular order. This technology can be used to detect forgery, intentional records falsification, email phishing campaigns, and corporate espionage.

■ Consumer-grade AI Applications

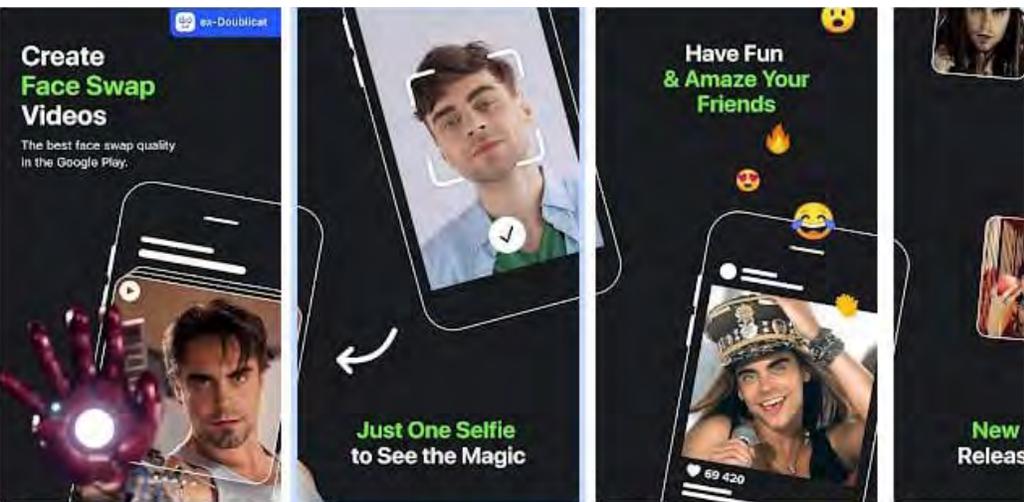
Low-code and no-code offerings from Amazon Web Services (AWS), Azure, and Google Cloud will start to trickle down to everyday people, who will create their own AI applications and deploy them as easily as they can a website. We're seeing a shift from highly technical AI applications used by professional researchers to more lightweight, user-friendly apps intended for tech-savvy consumers. New automated machine learning platforms make it possible for nonexperts to build and deploy predictive models. Platforms hope that in the near future, we'll use various AI applications as part of our daily work, just as we do Microsoft Office and Google Docs today.

■ Ubiquitous Digital Assistants Get Smarter

Digital assistants (DAs)—like Siri, Alexa, Google Assistant, and their Chinese counterpart, Tiān Mǎo from Alibaba—use semantic and natural language processing, along with our data, to anticipate what we want or need to do next, sometimes before we even know to ask. Alibaba's highly advanced DA can not only interact with real humans but also deftly handle interruptions and open-ended answers. Similar to Google Assistant's Duplex, Tiān Mǎo can make calls on your behalf, but it also understands intent. So if you're trying to schedule an appointment and mention that you're usually commuting in the morning, the system infers that you won't be available then. In 2017, Future Today Institute's analysis correctly projected that nearly half of Americans would own and use a digital assistant by 2020. (An estimated 62% of Americans

In some U.S. states, facial recognition without consent is now illegal. But there are no laws against emotional recognition.

Consumer Trends



The Reface app deepfakes consumer faces into popular movie scenes.

use digital assistants today.) Amazon and Google dominate the smart speaker market, but digital assistants can be found in many places. Thousands of applications and gadgets now track and respond to DAs. News organizations, entertainment companies, marketers, credit card companies, banks, local authorities, political campaigns, and many others can harness DAs to both surface and deliver critical information.

■ Deepfakes for Fun

Wombo is a lip-syncing app that allows consumers to transform any photo of a person into a video of that person singing. MyHeritage animates old photos. Faceswap is a free and open-source deepfake app powered by TensorFlow, Keras, and Python. Deep Art Effects offers desktop and mobile apps to turn images into stylized art. Reface is a face swap app that morphs your face onto celebrity bodies and creates GIFs to

share on social media. Jiggy is a deepfake that makes anyone dance. For now, they all result in images and GIFs that look like they've been manipulated—but with the technology becoming so easy to use, how long until we can't tell real from fake?

■ Personal Digital Twins

A number of startups are building customizable, trainable platforms capable of learning from you—and then representing you online via personal digital twins. In 2021, China's annual Spring Festival Gala on the country's state broadcaster (CCTV) included performances from synthesized celebrities. With an estimated billion people watching, the AI copies mimicked their human counterparts without pre-scripted behaviors, speeches, or routines. Meanwhile, Replika is a programmable digital twin that you can deploy for your friends. Molly, a Y Combinator-backed

startup, answers questions via text. The near future could include digital twins for professionals across a range of fields, including health and education.



00

01

02

03

04

05

06

07

08

09

10

11

12

13

Artificial Intelligence

Creative Fields



We are crossing a threshold into a new reality in which AI is generating its own programs, creating its own algorithms, and making choices without humans in the loop. At the moment, no one, in any country, has the right to interrogate an AI and see clearly how a decision was made.

— Amy Webb writing in *The Big Nine: How the Tech Titans and Their Thinking Machines Could Warp Humanity*



Creative Field Trends



Amazon's DeepComposer assists musicians with creating new melodies.

■ AI-Assisted Invention

Last year, the South African government granted a patent to an AI system called Dabus, which invented a method to interlock food containers. It was a world-first—previously, patents had only been awarded to humans. In the U.S., the application was rejected, with a judge citing case law stipulating that only a human can hold a patent. It begs the question: What happens when AI systems co-invent, or even entirely invent, new products?

■ Assisted Creativity

Generative adversarial networks (GANs) are capable of far more than generating deepfake videos. Researchers are partnering with artists and musicians to generate entirely new forms of creative expression. From synthesizing African tribal masks to building fantastical, fictional galaxies, AI is being used to explore new ideas. In

2019, Nvidia launched GauGAN (named after post-Impressionist painter Paul Gauguin), a generative adversarial AI system that lets users create lifelike landscape images that never existed. The National Institute of Informatics in Tokyo built an AI lyricist, while Amazon released its DeepComposer system, which composes music “automagically.” These AIs are not ostensibly intended to replace artists but rather to enhance their creative process.

■ Generative Algorithms for Content Production

During the 2022 Super Bowl, several ads made use of deepfakes, most notably a commercial featuring basketball star LeBron James talking to a de-aged version of himself. OpenAI's deep learning algorithm released a neural network called Jukebox that generates songs in a bunch of different styles and simulated voices that sound (sort of) like Elvis

Creative Field Trends



Looking in the mirror again and again

Wishing the reflection would tell me something

I, I can't get a hold of myself

— Haim

and others. The open-source algorithm DeepFaceLab has been used by other artists and filmmakers.

■ Neural Rendering

Starting with a 2D image, researchers can now create a rich 3D view of a scene using a neural network to capture and generate spatial imagery. Called neural rendering, the process captures a photorealistic scene in 3D by calculating the density and color of points in space. The algorithm converts 2D pixels into voxels, which are a 3D equivalent. The result is a video which looks convincingly real. The many applications for neural rendering include amping up autonomous driving to help train algorithms to recognize and react to novel on-road situations. This technology will influence the future of video games, virtual reality, and emerging metaverse environments.

■ Generating Virtual Environments from Short Videos

Nvidia is teaching AI to build realistic 3D environments from short video clips. The method builds on previous research on GANs. Nvidia's system generated graphics based on open-source datasets used by the autonomous driving field. Using short clips segmented into various categories—such as buildings, sky, vehicles, signs, trees, or people—the GANs created new, different versions of these objects. The array of possible applications is vast. Automatically generated virtual environments could be used for fantasy and superhero movies and could bring down the costs of TV production and game development.

■ Automated Versioning

Creating content can be a time-consuming, resource-intensive process. But new AI techniques could bring scale and

efficiency to everything from written articles to photo shoots. Virginia Tech researchers developed an algorithm that builds multiple versions of a single human model by breaking down an image into individual parts and then using a GAN to reposition the body. This technique allows a neural net to swap out clothing by fitting different pieces to a single body. Startup Flawless focuses on just one area of the body: the mouth. It generates international versions using deepfake dubs for TV shows and films, which match video with dialogue to create realistic new lip movements. Theoretically, a movie can be released in 100 languages simultaneously. Journalists at Switzerland-based Tamedia experimented with generative techniques during their country's 2018 election. A decision-tree algorithm Tamedia named Tobi generated automated articles detailing vote results for each municipality covered by the private media group's 30 newspapers. It also produced content

simultaneously in multiple languages. In total, Tobi published 39,996 different versions of election stories that averaged 250 words each. The articles carried a special byline alerting readers that they'd been written by an algorithm. With more experiments underway, we expect to see news and entertainment media companies developing multiple versions of the same content to reach wider audiences or to produce massive amounts of content at scale.

■ Automatic Voice Cloning and Dubbing

Anyone who's ever recorded a podcast is familiar with editing challenges such as guests talking over each other, interruptions from sirens and other background noises, and inconvenient sneezes. Those moments can stop a conversation cold. But what if you could edit the spoken word the way you edit a word document? That's the promise of AI companies including Resemble AI

Creative Field Trends



DeepFaceLab is an easy-to-use system that allows consumers to conduct high-quality face-swapping.

and Descript, which make it possible to clone voices. That means soon you might see a star like Phoebe Waller-Bridge in a movie and also hear her, in her own voice, speaking in Portuguese. Voice-over actors can now rent out their voices for use in a variety of languages. Resemble AI's system can translate English into 15 other spoken languages while learning thousands of features unique to one person's voice. But the technology is also attractive to cyber-criminals, who have started using it to infiltrate companies and dupe unwitting victims. Recently hackers used voice cloning tools to trick an employee into thinking he was speaking on the phone to his CEO; he then transferred \$243,000 to a scammer's bank account.

■ Automatic Ambient Noise Dubbing

For some time, we've been training computers to watch videos and predict corresponding sounds in our physical

world. For example, what sound is generated when a wooden drumstick taps a couch? A pile of leaves? A glass windowpane? The focus of this research, underway at MIT's Computer Science and Artificial Intelligence Laboratory, should help systems understand how objects interact with each other in the physical realm. Numerous projects are now underway to make it easier to automatically generate voices, videos, and even storylines.

■ Ambient Interfaces

Modern interfaces are able to do more for us with fewer direct actions—yet still captivate our attention. The average adult now makes more than 20,000 decisions a day—some big, such as whether to invest in the stock market, and some small, such as whether to glance at a mobile phone when the screen lights up. Zero user interfaces—otherwise known as ambient computing systems—promise to prioritize those decisions,

delegate them on our behalf, and even autonomously answer for us, depending on the circumstance. Much of this invisible decision-making will happen without direct supervision or input from people. What makes ambient design so tantalizing is that it should require us to make fewer and fewer decisions in the near future. Think of it as a sort of autocomplete for intent.



00

01

02

03

04

05

06

07

08

09

10

11

12

13

Artificial Intelligence

Health, Medicine & Science

Health, Medicine and Science Trends



AI is being used to speed the development of new therapeutics.

■ Protein Folding

In 2020, DeepMind's AI made a big announcement: It had solved a 50-year grand challenge with AlphaFold, an AI tool that predicts the structure of proteins. AlphaFold outperformed an estimated 100 teams in a biennial protein-structure prediction challenge called Critical Assessment of Structure Prediction. Predicting protein structures has long vexed biologists. AlphaFold had previously bested other teams, but it worked so quickly and so accurately that it signaled a near future when the technology could be used regularly by other scientists.

Along with the newest version of AlphaFold, DeepMind published full details of the system and released its source code. It also made a stunning reveal: AlphaFold 2 has predicted the shapes of nearly every protein in the human body, as well as hundreds of thousands of other proteins found in 20 of the most widely

studied organisms, including yeast, fruit flies, and mice. All of this research will allow biologists to study and gain new insights on living organisms and pathogens, which will form the basis for new drug development.

■ AI Speeds Scientific Discovery

Running experiments with several variables often requires tiny, methodical tweaks to measurements, materials, and inputs. Graduate students might spend hundreds of tedious hours repeatedly making small adjustments until they find a solution—a waste of their cognitive abilities. Research labs now use AI systems to speed the process of scientific discovery. Biotechnology company Recursion uses computer vision-based digital biomarkers, such as respiratory rate, to assess and track disease. Digitalizing in vivo studies will further shorten the time to gather data and identify drug efficiency. Materials

scientists at the University of British Columbia now rapidly test a new kind of solar cell and log results using a robot overseen by an AI algorithm. Based on the results of each experiment, the algorithm determines what to change next. A 9- to 12-month process was completed in 5 days. DeepMind's AlphaFold will allow scientists to synthesize new drugs to treat diseases and develop enzymes that might someday break down pollution.

■ AI-First Drug Discovery

COVID-19 accelerated the use of AI in drug discovery. An international team crowdsourced a COVID antiviral by synthesizing candidates for 2,000 molecules in less than 48 hours—a process that likely would have taken human researchers a month or longer. In Japan, the first phase of a clinical trial for an AI-designed drug to treat obsessive-compulsive disorder showed a positive result. The drug, DSP-1181, acts as

Health, Medicine and Science Trends

an agonist to the receptor for serotonin, a signaling molecule in the brain that mediates mood. The project used AI techniques to generate tens of millions of potential molecules to try against the serotonin receptor and sift through the candidates to decide which ones to prioritize for synthesis and testing.

AI-first drug startups are attractive to investors. Recursion raised \$121 million in 2019 before spinning off CereXis, a new independent entity to study rare brain cancers. Nearly every major pharmaceutical company has inked deals with AI drug discovery startups, including Johnson & Johnson, Novartis, Merck, AstraZeneca, and GlaxoSmithKline. Much of the potential in AI stems from deep learning's ability to sort through huge volumes of information and learn and extrapolate from that information. The upshot: AI can think faster than humans—sorting data in months versus years—and see patterns that we

may not. Still, drug discovery is tricky, because the algorithms rely on drug targets that must be published in research journals. Most data about potential compounds isn't readily available, and when it is, it isn't always complete or reliable. Filling the gaps and cleaning that data takes time and money. It also requires data sharing—and most drug data is proprietary and locked up by big drugmakers. Using algorithms for drug development also brings up a host of ethical questions. Will bias invade drug discovery much like it has other arenas of AI, thereby marginalizing certain patients or diseases? Do algorithms need their own clinical trials? Could AI be used to take shortcuts and undermine the value of the science being done inside the laboratory? Advocates say AI will make drug development and clinical trials more efficient, thereby cutting drug prices and paving the way for more personalized medicine.

■ AI Improves Patient Outcomes

New medical algorithms address the level of patient care in the U.S. Patients experience symptoms differently, and their care is based on how they describe their symptoms and how those symptoms are interpreted by doctors. For example, assessing the severity of arthritic pain is challenging. There is a standard scoring system to rate pain, which looks at the amount of structural damage and missing cartilage, but data from the National Institutes of Health found that Black patients' pain is underscored. It's likely that the system itself, called the Kellgren-Lawrence Grade, was riddled with bias when it was first developed using primarily white British patients. Researchers are training deep learning models instead, and finding gaps in patient care.

■ Deep Learning Applied to Medical Imaging

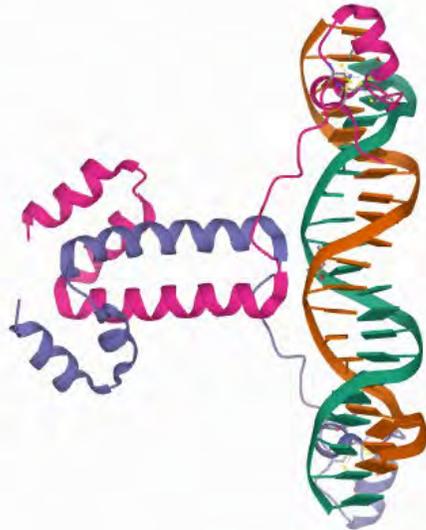
A new system designed to improve stroke outcomes, Viz.ai, showed promising results last year in a real-world study. An AI-based approach reduced the amount of time it took to detect a brain stroke by 39%, which resulted in more patients identified as eligible for thrombectomy, a procedure that reduces the chances of long-term disability. Radiologists and pathologists increasingly rely on AI to assist them with diagnostic medical imaging. In 2021, U.S. Food and Drug Administration approvals allowed new products to be used widely in hospitals and clinics. So far, most of the approved devices augment (rather than fully automate) the process of reviewing images and making diagnoses. But emerging autonomous products are making their way into clinical settings. IDx-DR is an AI-enabled device that detects diabetic retinopathy using retinal images. Caption Health uses AI

to capture ultrasound images of the heart that expands who can read such scans. Nurses would just need a few days of training on the software.

■ Self-Driving Microscopes

Researchers at the Oak Ridge National Laboratory are applying deep learning to microscopy, which until now had relied on humans to painstakingly organize, observe, and analyze microscopic samples. Deep learning will automate much of that process while also extracting more information from samples. A smart microscope would be able to view and analyze samples in real time—while techniques that introduce a stimulus, such as an electric field, will allow researchers to gain real-world understanding in more dimensions and on a nanoscopic scale. This could become a force multiplier in how scientific discovery is done.

Health, Medicine and Science Trends



DeepMind hopes to predict a wide array of protein shapes.

■ NLP Algorithms Detect Virus Mutations

Natural language processing (NLP) algorithms, which are typically used for words and sentences, are being used to interpret genetic changes in viruses. Protein sequences and genetic codes can be modeled using NLP techniques—and can be manipulated the way you'd produce text in word processing software. At MIT, computational biologists used NLP to solve a vexing problem when developing new vaccines. “Viral escape” is the ability for a virus to mutate and evade the human immune system and cause infection. MIT researchers modeled viral escape using NLP to identify how the virus might look different to the immune system. The approach is similar to changing words in a sentence to change its meaning. For example: “I laughed at the clown” versus “I cried at the clown.”

By using this kind of modeling before mutations occur, public health officials could strategize and potentially prevent new viral spreads.

■ Using AI to Improve Talk Therapy

The success of therapy and counseling requires trust between a clinician or doctor and patient—and that trust is built through dialogue. AI is now being used to quantify linguistic interactions to determine what techniques work best. Startup Lyssn translates natural language into structured data and generates digital voiceprints, which identify the sentiment attached to each sound. It's hoped that this technology will be used to improve the techniques therapists use for cognitive behavioral therapy, PTSD therapy, and other forms of talk therapy delivered in-person or via telemedicine.

■ Dream Communication

Scientists discovered how to establish two-way communication channels between lucid dreamers. Lucid dreamers are aware that they are asleep and can steer their dreams. In four global studies, participants were outfitted with sensors attached to their heads and faces, and their data was fed into a computer that looked for patterns. Scientists verified a state of REM sleep, and then participants interacted with researchers using eye movements. The study proved that there are new ways to send and receive real-time information while dreaming. Meanwhile, researchers at MIT's Dream Lab built a wearable device that can track and interact with dreaming sleepers. A glove, outfitted with different sensors, plays prerecorded audio cues depending on the wearer's current state of sleep. Scientists at MIT, Harvard, and the University of Montreal are warning that advertisers could begin

to alter and drive purchasing behavior through sleep and dream hacking.

■ Thought Detection

Deep neural networks are being used to analyze emotional states using wireless signals. Researchers at Queen Mary University of London used radio signals to measure subjects as they watched a video. The deep neural network analyzed subtle body movements—breathing rates, heart rate—to reveal otherwise hidden information. If this reminds you of the “Black Mirror” “Crocodile” episode, you're not far off: Research labs are developing new technologies to read our minds. There are business implications: HR departments could determine what employees really think of company policies, lawyers could determine how jurors lean in a case, and realtors could judge how serious a homebuyer is. But the ethics are, of course, concerning.

The Real Future of AI

In the future, AI will be able to evolve on its own, creating new and better versions of itself. This process will be known as “self-evolution.” Self-evolution will allow AI to become smarter and more efficient over time. It will also enable AI to adapt to new environments and situations, making it more versatile and powerful. AI has already shown signs of self-evolution in recent years. For example, Google’s AlphaGo program was able to learn how to play Go better than any other program by playing against itself. As AI continues to evolve, we can expect even more impressive feats from it – including

self-evolved machines that are smarter than humans.

In the future, AI will be so advanced that it will be indistinguishable from actual intelligence.

Humanity will achieve a level of technological singularity, and all our questions about the universe will be answered. We will also create powerful robots that can do everything humans can do, only better. These robots will eventually become self-aware, and we will have to deal with the consequences of creating something that is essentially equal to us.

This scenario was written by GPT-3, OpenAI’s language generator. (Humans did design the page, however.) GPT-3 was given the following instructions by Amy Webb, the Future Today Institute’s CEO: “Please write a short op-ed around 500 words. Focus on how AI will evolve in the future. Make it sound like science fiction but keep it factual.” Amy used GPT-3 to produce several different outputs, and selected this scenario as her favorite. It took 3.29 seconds for GPT-3 to write this essay, which Amy decided required little editing.



00

01

02

03

04

05

06

07

08

09

10

11

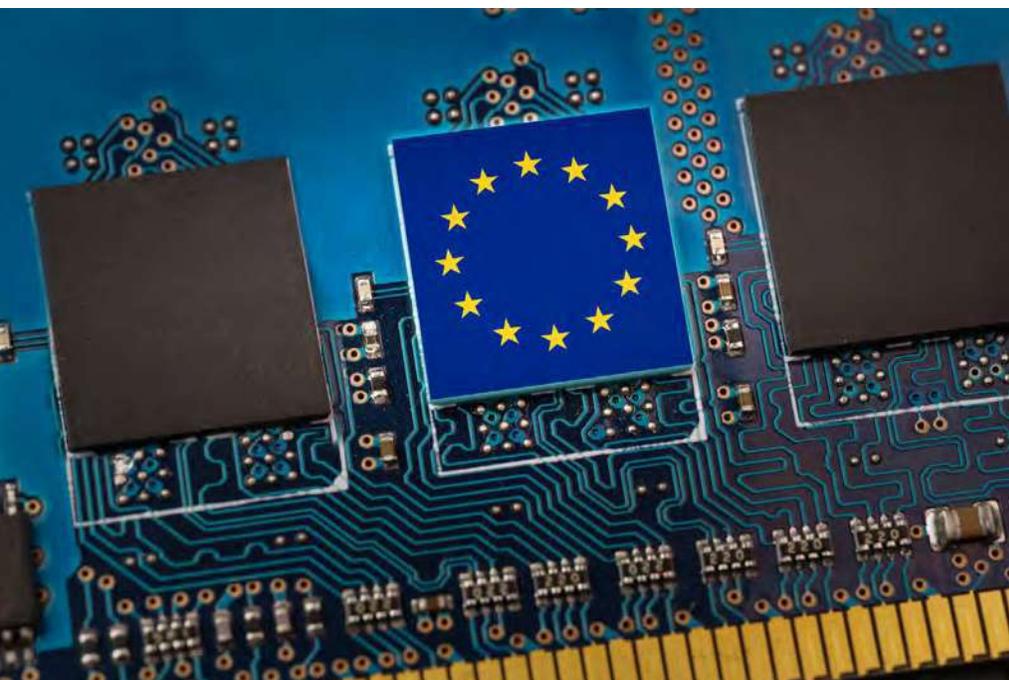
12

13

Artificial Intelligence

Geopolitics & Military

Geopolitics Trends



This year, the EU could pass a sweeping set of AI regulations.

■ The European Approach to Regulating AI

Last year, the European Commission introduced a new proposal to regulate the use of artificial intelligence. The AI Act (AIA) is intended to promote both innovation and consumer protection. It distinguishes between “high risk” and “low risk” systems. For those categorized as high risk, AI systems must meet several criteria: (a) they should work as the user intended and should be interpretable; (b) they should be secure and accurate; (c) they should contain all necessary technical documentation for proper use and keep logs of their behavior; (d) they must have effective human oversight. The AIA would cover any person or organization (including foreign entities) that use an AI system housed within the EU. If adopted, the new regulation would prohibit social scoring, real-time remote biometric sensing and analysis, and any techniques that might target and distort a person’s behavior. It isn’t

clear that the AIA would be enforced meaningfully, or that the cost of compliance would be reasonable.

■ AI Nationalism

Governments are instituting new restrictions on mergers and acquisitions and investment activity to ensure that AI developed by companies does not aid foreign adversaries. The U.S. Senate overwhelmingly passed legislation last June, dedicating \$250 billion to scientific and technological research. Its centerpiece, the Endless Frontier Act, was designed to boost U.S. competitiveness against China, especially in AI. It also creates a new technology directorate within the National Science Foundation with \$100 billion in funding over five years and earmarks \$10 billion for local and regional tech hubs across America. Meanwhile, in China the Ministry of Science and Technology established 20-city AI pilot zones that should open by 2023. They will carry out AI-based

policy experiments and social experiments, according to official government documents. Meanwhile, China is planning for a world without American technology, with government directives to prioritize homegrown technology companies and software systems.

■ National AI Strategies

China passed its New Generation Artificial Intelligence Development Plan with aggressive benchmarks to become the world’s dominant AI player within 10 years; France adopted a national strategy called AI for Humanity; Saudi Arabia has both a strategy and a legal framework for making robots citizens; and the United Arab Emirates has a sweeping set of policy initiatives on AI and appointed Omar Sultan Al Olama as its minister of state for artificial intelligence. In the U.S., numerous public and private groups work independently on the future of AI on behalf of the nation. Those efforts, however, lack interagency

Geopolitics Trends

collaboration and coordinated efforts to streamline goals, outcomes, R&D efforts, and funding. A new wave of countries will launch national AI strategies this year. The OECD AI Policy Observatory now maintains a live repository of more than 700 AI policy initiatives from 60 countries, territories, and the EU.

■ AI as Critical Infrastructure

Government researchers are exploring ways to spearhead AI development for critical systems use: road and rail transportation systems; power generation and distribution; and predicting routes for public safety vehicles, such as ambulances and firetrucks. Rather than shunning AI systems, there is new interest in using the technology to prevent disasters and improve safety.

■ Nation-based Guardrails and Regulations

From self-driving car accidents to elec-

tion interference through disinformation campaigns to political repression enhanced by facial recognition and automated surveillance, major events over the past few years have thrown into sharp relief the dangers of artificial intelligence. Few guardrails exist for a technology that will touch every facet of humanity, and countries are racing to develop and publish their own AI strategies and guidelines. The European Union developed an AI Alliance and plan of cooperation between member countries, and Estonia is developing its own legal framework governing the use of AI within the country. In 2020, China moved into position to lead the first set of global AI norms and standards. It had previously published a report on technical standards that would allow companies to collaborate and make their systems interoperable. The EU and the Organization for Economic Cooperation and Development similarly published their own guidelines. While

these efforts could introduce new ways to safeguard against bias and to ensure trust, they also each attempt to create strategic advantages for stakeholders. As AI continues to develop according to different rules in China, the EU, and the U.S., one of the hallmarks of the field—global academic collaboration—could drastically decline.

■ Regulating Deepfakes

The U.S. National Defense Authorization Act includes provisions that address the growing problem of deepfakes, and the Department of Homeland Security must now issue an annual report each year for the next five years on the risk posed by deepfakes. Last August, the U.S. Senate Committee on Homeland Security and Governmental Affairs voted unanimously to advance the Deepfake Task Force Act, which would establish a public-private team built to investigate technology strategies and policy that could curb risk. Bills to regulate or

prohibit the use of deepfakes have been introduced in California, Texas, and Massachusetts, and a number of federal bills are being discussed. These initiatives will likely be met with arguments that prohibiting deepfakes infringes on free speech rights.

■ Making AI Explain Itself

You've undoubtedly heard someone argue that AI is becoming a "black box"—that even researchers working in the field don't understand how our newest systems work. That's not entirely true. However, there is growing concern among computer scientists, journalists, and legal scholars who argue that AI systems shouldn't be so secretive, and regulators are paying close attention. Broadly speaking, a few challenges must be overcome. Requiring transparency in AI could reveal a company's trade secrets. Asking the systems to explain their decision-making processes as they work could also degrade the speed and

quality of output. It's plausible that various countries will enact new regulations requiring explainability in the coming years. Imagine sitting beside a genius mathematician who gives you correct answers in Italy, but receiving her answers across the border in France would mean asking her to stop and show her work—and every time she's asked to share her answers in a new country.

■ New Strategic Technical Alliances

New strategic technical alliances between countries will help drive future R&D but could also strain existing geopolitical alliances or heighten tensions. Likely partners include the U.S., Germany, Japan, India, South Korea, the U.K., France, and Canada—leaving China and Russia to partner up separately. The latter two countries have already announced a technical alliance on satellites and deep-space exploration.

Military (U.S. Focus) Trends



A U-2 spy plane prepares to land at Beale Air Force in California. The U-2 Federal Laboratory trained an AI copilot to execute specific in-flight tasks that would otherwise be done by the pilot.

Image credit: Airman 1st Class Luis A. Ruiz-Vazquez/USAF.

■ AI to Guide Air Strikes

In 2021, the U.S. military said that it had started using AI to guide its airstrikes, deploying algorithms to a live operational kill chain. The kill chain is a process of gathering intelligence, performing analysis, weighing risks, and deploying weapons to destroy a target. Using a modified process, an AI system was deployed into the Air Force Distributed Common Ground System to analyze troves of intelligence, which would have required a significant amount of human hours to complete. The new AI system cannot order a strike on its own, but it is now automatically identifying possible targets.

■ Algorithmic Warfighting

Future wars will be fought in code, using data and algorithms as powerful weapons. The current global order is being shaped by AI, and the same

countries leading the world in AI research—the U.S., China, Israel, France, Russia, the U.K., and South Korea—are also developing weapons systems that include at least some autonomous functionality. The U.S. Air Force has successfully flown an AI copilot on a U-2 spy plane in California, marking the first time in the history of the Department of Defense that an AI algorithm trained to execute specific in-flight tasks was deployed. With the call sign ARTUμ, it was the mission commander—though the flight was just practice. Future Today Institute analysis shows that the future of warfare encompasses more than traditional weapons. Using AI techniques, a military can “win” by destabilizing an economy rather than demolishing countrysides and city centers. From that perspective, China’s unified march to advance AI puts the emerging superpower dangerously far ahead of the West.

■ Ethics Guidelines for Tech Contractors

Project Maven was developed to enlist AI to analyze surveillance video. Initially, Google was the DOD’s vendor, but when employees found out they’d been working on a military project, thousands protested. It wasn’t the first time tech contractors had lost trust in the government. As a result, the Defense Innovation Unit is enforcing “responsible artificial intelligence” guidelines that vendors must adopt when building AI systems, models, or applications for the DOD. The guidelines offer specific instructions that must be followed during planning, development, and deployment, which include provisions for risk assessment. This represents a longer-term trend: government agencies requiring transparency in AI projects.

Military (U.S. Focus) Trends



The AI algorithm known as ARTUμ flew with pilot U.S. Air Force Maj. “Vudu” on a U-2 Dragon Lady assigned to the 9th Reconnaissance Wing at Beale Air Force Base. Air Combat Command’s U-2 Federal Laboratory researchers developed ARTUμ and trained it to execute specific in-flight tasks that otherwise would be done by the pilot.

■ The Mil-Tech Industrial Complex

In 2021, U.S. President Joe Biden announced a Pentagon budget request with \$874 million earmarked for direct investment in AI. In the U.K., the government announced an investment of 6.6 billion pounds into military R&D over the next four years, while the EU launched a 8 billion euros European Defense Fund with a focus on AI through 2027.

In the past few years, some of the biggest AI companies in the U.S. have partnered with the military to advance R&D and find efficiencies. In fact, the public sector cannot advance its technology without help from outside companies. Microsoft’s \$22 billion contract for HoloLens builds on a previous prototyping contract worth \$480 million in 2018 and a \$10 billion cloud contract in 2019. Anduril Industries, an AI-powered drone company, was awarded a \$99 million five-year production order contract with the DOD and will rely on Google Cloud to

develop a virtual wall at the U.S.-Mexico border to automatically detect migrants and traffickers.

The U.S. General Services Administration and the DOD’s Joint Artificial Intelligence Center awarded a five-year, \$800 million contract to Booz Allen Hamilton for AI product development. The U.S. Army awarded Lockheed Martin a \$75 million contract for a machine learning cyber jamming pod that can be mounted on Humvees or drones. With a new focus on defense roadmaps that include AI components, startups working in high-resolution satellite imagery, computer vision, and unmanned aerial vehicles are attracting lucrative venture capital investment.

While the DOD called off its controversial \$10 billion Joint Enterprise Defense Infrastructure (or JEDI) cloud contract that pitted Microsoft and Amazon in a legal battle against each other, a new multi-vendor cloud computing contract will be awarded. The new program, the

Joint Warfighter Cloud Capability, will solicit proposals from both Microsoft and Amazon, as they are likely the only cloud service providers that can currently meet the needs of the U.S. military.

Many of these contracts have prompted employee protests. In just one example: Google employees were at one point directed to train AI systems to analyze drone footage—but they weren’t told the project, known as Maven, was for the DOD. A high-profile backlash ensued: As many as 4,000 Google employees signed a petition objecting to Project Maven, and ultimately dozens resigned. Eventually, Google said it wouldn’t renew its contract on the project. The company launched a set of ethical principles governing its development and use of AI, including a provision that prohibits any systems from being used for “weapons or other technologies whose principal purpose or implementation is to cause or directly facilitate injury to people.”

China Spotlight



President Xi Jinping wants China to become the dominant AI force by 2030.

China is an undisputed global leader in artificial intelligence. Under President Xi Jinping, the country has made tremendous strides in many fields, but especially in AI. Businesses and the government have collaborated on a sweeping plan to make China the world's primary AI innovation center by 2030, and it's already making serious progress toward that goal. That plan is unlikely to be repealed by a new government; China abolished Xi's term limits and will effectively allow him to remain in power for life.

Within the next decade, China plans to meet two crucial milestones: By 2027, its People's Liberation Army will have a modern-ready force, and by 2030 the Chinese Communist Party (CCP) expects to have outpaced the U.S. in AI and become the singular dominant force. China is producing what it calls "intelligentized" technologies to bolster both its economy and military.

Last year it took major steps into shaping the future of AI by releasing its own pretrained models. China is forging ahead on its own natural language processing models, which makes sense: The most popular models in use now are trained on English text. Researchers from Tsinghua University and Alibaba are developing Chinese datasets and pretrained large transformers to compete against the likes of GPT-3. In 2021, two models developed specifically for the Chinese language went live: Wu Dao 2.0 and M6.

The country's enormous population of 1.4 billion offers researchers and startups there a command of what may be the most valuable natural resource in the future—human data—without the privacy and security restrictions common in much of the rest of the world. If data is the new oil, then China is the new OPEC. The kind of rich data the Chinese are mining can be used to train

China Spotlight

AI to detect patterns used in everything from education to manufacturing to retail to military applications.

That gives China an incredible advantage over the West. It also gives three of China's biggest companies—Baidu, Alibaba, and Tencent—superpowers. Collectively, they're known as the BAT, and they're all part of the country's well-capitalized, highly organized AI plan.

The BAT is important to you even if you've never used them and don't do any business in China. That's because these companies are now well established in Seattle and around San Francisco, and they are investing significantly in U.S. startups. Baidu (a search engine company often likened to Google) established AI research centers in Silicon Valley and Seattle, and Tencent (the developer of the mega-popular messaging app WeChat) began hunting for American talent when it opened an AI lab in Seattle a few years ago. It has since upped

its stakes in companies including Tesla and Snap. The payoff for the Chinese is not just a typical return on investment—Chinese companies expect IP as well. China-based AI startups now account for nearly half of all AI investments globally.

Expanding market

In February 2022, Tencent made the list of the world's 10 most valuable companies, with a valuation of \$589 billion. (Its valuation soared to \$1 trillion in 2021, but after CCP regulators cracked down on its tech giants last year, the share price slid.) Since 2018, Alibaba's sales have tripled, from less than \$40 billion to more than \$126 billion, according to data from S&P Global Market Intelligence.

Chinese startup SenseTime is pioneering myriad recognition technologies, such as a system that provides advertisers real-time feedback on what people

are watching; technology that can extract customer information and carry out statistical analysis in crowded areas like shopping malls and supermarkets; and simultaneous recognition of everything in a scene, including people, pets, automobiles, trees, or soda cans. In 2020, it generated \$525 million in revenue and is now worth \$12 billion today.

China's AI ethics

The CCP's Chinese Governance Committee for the New Generation Artificial Intelligence released a draft of its new ethical norms and standards that all AI systems must conform to. The norms cover areas such as the use and protection of personal information, human control over and responsibility for AI, and the avoidance of AI-related monopolies. There are no provisions yet explaining how the norms would be enforced, or what punishments could follow. It's also unclear whether foreign

companies that use or deploy AI technologies within China would also need to comply with the new ethics rules.

Cracking down on Big Tech

Last year, the CCP initiated a wave of legislation aimed at its tech sector. Regulators introduced anti-monopoly legislation focused on the platform economy and promoted data security and privacy laws. The Personal Information Protection Law (PIPL), China's version of the EU's GDPR, went into effect November 2021. Next, they will tackle AI-specific regulation, including recommendation algorithms. The crackdown specifically targeted Alibaba, which was fined \$2 billion. Didi, the country's largest ride sharing service, was prohibited from registering new users while regulators conducted a cybersecurity review—which analysts say had more to do with Didi listing itself on the New York Stock Exchange than any security problems.

Chinese companies choosing to list on U.S. stock exchanges could face regulatory scrutiny and auditing. Ultimately, this regulation isn't about "breaking up" China's Big Tech—the CCP wants to focus its tech sector on achieving research and development goals set by the government and military within the decade.

Strategic panopticon

In late 2019, China began requiring all citizens to submit to facial recognition in order to apply for new internet or mobile services, and began requiring that telecom companies deploy AI to check the identities of people registering SIM cards. Chinese social media platforms require users to sign up with their real names. In Chinese schools, surveillance cameras with computer vision are used widely and track whether students are paying attention and whether they attempt to cheat or sleep. These and

China Spotlight

other national standards make it easier for the government to track its citizens. China's social credit system, an algorithmic reputation system developed by the government, standardizes assessments of citizens' and businesses' behavior and activity.

In 2020, numerous reports of abuse revealed that China turned its AI on the ethnic Uyghur Muslim community. Huawei developed special AI software to identify Uyghurs and alert local police. In 2021, China blocked social media platform Clubhouse after an open, democratic debate flourished on the platform about the plight of the Uyghur community.

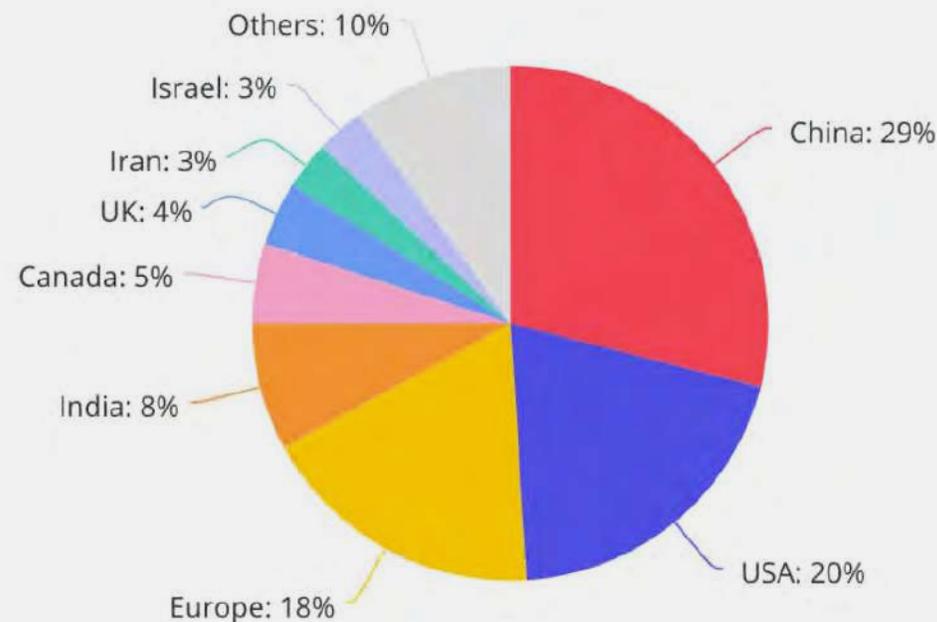
Risk profile

We have failed—and we are continuing to fail—to see China as a military, economic, and diplomatic threat when it comes to AI. China has already used its Belt and Road Initiative as a platform to

build international partnerships in both physical and digital infrastructure, and it is making surveillance technologies available to countries with authoritarian regimes. Two Chinese companies—the state-controlled CEIEC and Huawei—built Ecuador's surveillance system, called ECU-911. The system promised to curb high murder rates and drug crime, but it was too expensive an investment. As a result, a deal was struck for a Chinese-built surveillance system financed with Chinese loans. It was a prelude to a much more lucrative deal: Ecuador eventually signed away big portions of its oil reserves to China to help finance infrastructure projects. Similar package deals have been brokered in Venezuela and Bolivia.

China is quietly weaponizing AI, too. China's People's Liberation Army is catching up to the U.S. military, using AI for such tasks as spotting hidden images with drones. The Chinese military is

Top-tier AI Researchers Increasingly Hail From China



Country affiliations are based on the country where the researcher received their undergraduate degree.

Source: <https://macropolo.org/digital-projects/the-global-ai-talent-tracker/>

China Spotlight



China is rapidly expanding its digital footprint.

equipping helicopters and jet fighters with AI. The government created a top-secret military lab—a Chinese version of DARPA—and it's building billion-dollar AI national laboratories. China's military is achieving remarkable AI successes, including a recent test of “swarm intelligence” that can automate dozens of armed drones.

China's supremacy

We're living through a precarious moment in time. China is shaping the world order in its own image, while exporting its technologies and surveillance systems to other countries. As China expands into African countries and throughout Southeast Asia and Latin America, it will also begin to eschew operating systems, technologies and infrastructure built by the West. China has already announced that it will no longer use U.S.-made computers and software. China is rapidly expanding its

5G and mobile footprints. At the same time, China is drastically expanding its trading partners. While India, Japan, and South Korea have plenty of technologies to offer the world, it would appear as though China is quickly ascending to global supremacy. At the moment, the U.S. is enabling this, and our leaders do not appear to be thinking about the long-term consequences.

When it comes to AI, we should pay close attention to China, which has talked openly about its plans for cyber sovereignty. But we should also remember that there are cells of rogue actors who could cripple our economies simply by mucking with the power or traffic grids, causing traffic spikes on the internet, or locking us out of our connected home appliances. These aren't big, obvious signs of aggression, and that is a problem for many countries, including the United States. Most governments don't have a paradigm describing a constella-

tion of aggressive actions. Each action on its own might be insignificant. What are the escalation triggers? We don't have a definition, and that creates a strategic vulnerability.

—Amy Webb



00

01

02

03

04

05

06

07

08

09

10

11

12

13

Artificial Intelligence

Research

Research Trends

Three research teams from Microsoft, Google, and Baidu have surpassed human baselines on SuperGLUE NLP tasks.

From AlphaGo to MuZero and Beyond

In 2016, DeepMind unveiled AlphaGo, the first AI program capable of defeating human players at Go—a board game long held as the high-water benchmark in the field. Then, in 2018, the team created a successor called AlphaZero, which learned how to master Go, chess and shogi (an ancient Japanese chess game)—from scratch, without human trainers. Last year, DeepMind published a stunning paper in the journal Nature describing MuZero, which mastered all previous tasks plus Atari without needing to be told the rules. This was a significant step toward AI systems functioning in unknown environments—and yet another sign that general-purpose algorithms are on the horizon.



Is artificial intelligence less than our intelligence?

— Spike Jonze, filmmaker

Research Trends

■ Supersized AI Models

Last year, we saw the proliferation of large AI models—but supersized models are on the horizon. For context, GPT-3—widely hailed as a powerhouse—has 175 billion parameters. Huawei debuted a 200 billion parameter language model called Pangu, while Baidu and the Peng Cheng Lab released PCL-BAIDU Wenxin, with 280 billion parameters. PCL-BAIDU is already deployed to Baidu’s news feeds, search engine, and digital assistant. Gopher, which was released by DeepMind in December 2021, has 280 billion parameters. And Microsoft’s Megatron-Turing NLG, built in collaboration with Nvidia, has 530 billion parameters. Google’s Switch-Transformer and GLaM models have a staggering 1 trillion and 1.2 trillion parameters, respectively—but even bigger is Wu Dao 2.0 from the Beijing Academy of AI, which reportedly has 1.75 trillion parameters.

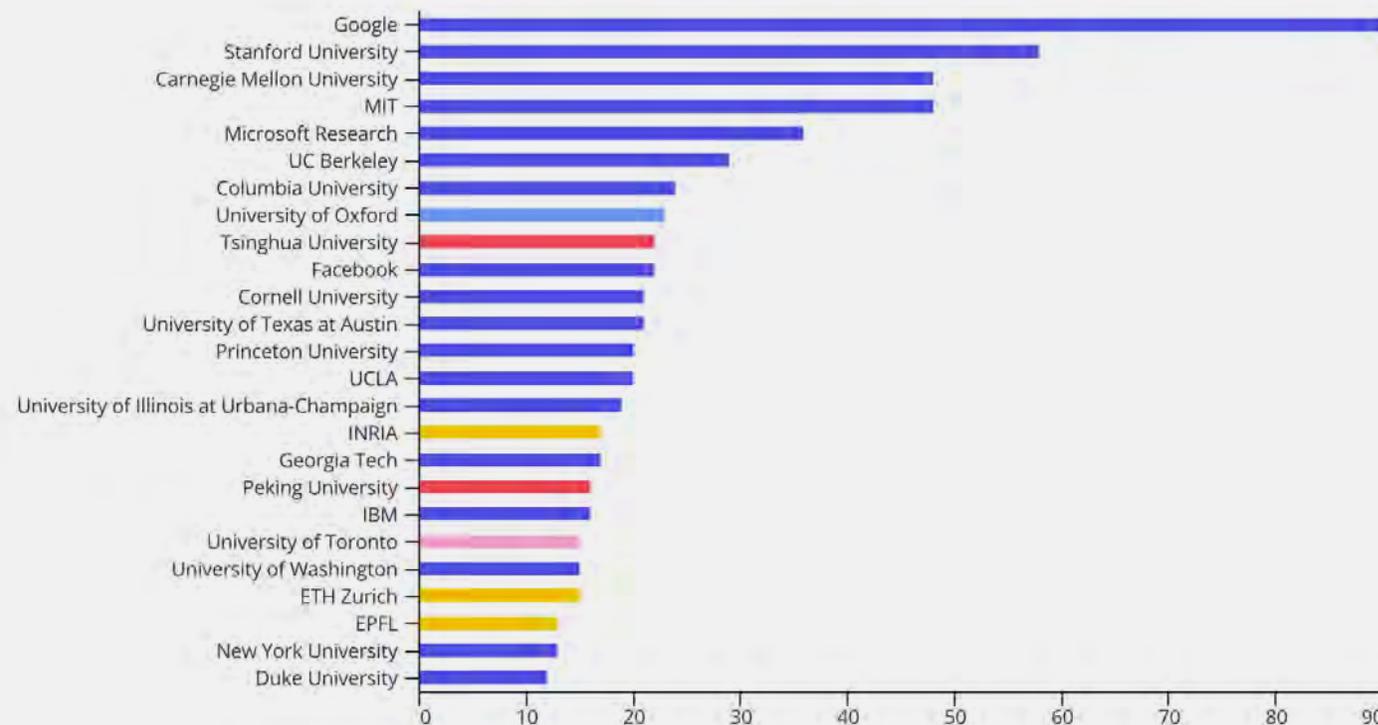
■ Unified Learning Processes

Deep neural nets are good at identifying objects in photos and videos and processing natural language, but until recently models had to be trained separately. Researchers have now developed Data2vec, a system that deploys a single algorithm to train a neural network to recognize images, text, or speech. It unifies the learning process through self-supervised learning, which allows the neural net to recognize patterns in datasets on its own, without being fed labeled examples.

■ Textless NLP

Most large language models have been trained on publicly available datasets such as Reddit and Wikipedia. Both are rife with biases. Researchers are developing generative spoken language modeling, which extracts speech from raw audio without labels or text. The hope is that AI could become more inclusive if

The Top 25 Institutions for Top-Tier AI Research



Source: <https://macropolo.org/digital-projects/the-global-ai-talent-tracker/>

Research Trends

it uses podcasts, local radio, and other sources of spoken language.

■ Closed-Source Code

Code is important for reproducibility, accountability, and transparency, and it is a key to driving improvements in the greater AI community. But when academic researchers publish papers, they don't often include all of their code. The reason given: The code they used is intermingled with other proprietary research, and it therefore can't be released. Fewer than 20% of all academic papers on AI publish their full code, and some big names—DeepMind and OpenAI—notoriously leave theirs out, citing proprietary concerns.

■ Framework Consolidation

Google's TensorFlow and Facebook's PyTorch are two popular frameworks used by researchers, and the relative popularity of different frameworks typ-

ically mirrors trends in the commercial application landscape. In the past five years, Facebook seems to have gained ground. Of the conference papers that mention the framework the researchers used, 75% cited PyTorch but not TensorFlow. Of the 161 researchers who published more TensorFlow papers than PyTorch papers, 55% of them switched to PyTorch, while only 15% moved in the other direction.

■ Lowering the Cost of Training Models

It costs a lot to train a model. Several variables influence those costs, all of which have increased in the past few years. For example, it costs an average of \$1 per 1,000 parameters. OpenAI's GPT-3, likely cost more than \$10 million to train. For smaller research groups and companies, the costs are out of reach. Some in the AI community are instead allowing the big tech companies to pretrain and publish big models.

■ Surpassing NLP Benchmarks

The General Language Understanding Evaluation (GLUE) benchmark is a collection of resources for training, evaluating, and analyzing natural language understanding systems. It includes a benchmark of tasks around understanding nine sentences or a pair of sentences built on existing datasets and selected to cover a diverse range of dataset sizes, text genres, and degrees of difficulty. It includes a diagnostic dataset designed to evaluate and analyze model performance with respect to a wide range of linguistic phenomena found in natural language. And it includes a public leaderboard so that researchers can track their performance. The human baseline score is 87, and between May 2018 and August 2020, natural language processing systems increased from 60 to 90.6, surpassing humans. The SuperGLUE benchmark is a new measurement of more difficult language understanding tasks, improved resources, and a new public leader-

board. When SuperGLUE was introduced, there was a nearly 20-point gap between the best-performing model and human performance on the leaderboard. Last year, AI models from Microsoft and Google surpassed human performance. Existing language benchmarks still fail to capture biases encoded in public data—future benchmarks could be designed to resolve this gap.

■ No Retraining Required

Training robots to do more than one thing is difficult, but a new model pits identical robot arms against one another in a game (moving objects on a virtual table in specific ways) in which one robot challenges the other with increasingly difficult tasks. It's an example of multitask learning, a deep learning model in which machines learn different skills as they progress. OpenAI's model allows a bot to solve new kinds of problems without requiring retraining.

■ Proliferation of Franken-Algorithms

Algorithms are simply rules that define and automate the treatment of data. They are built using “if this, then that” logic that a computer can understand and process. Here's an easy example: If a website reader's IP address is based in Baltimore, the rules then allow that reader to freely access the site; if the IP address is based in Belgium, then the rules first show a GDPR screen stating privacy and cookie policies. While a single algorithm might be easily described and deployed as expected, systems of algorithms all working together can sometimes pose problems. Developers don't always know in advance how one algorithm will function alongside other algorithms. Sometimes, several teams of developers are working independently on different algorithms and datasets, and they only see one another's work once it is deployed. This has been the cause of recent stock market glitches

Research Trends

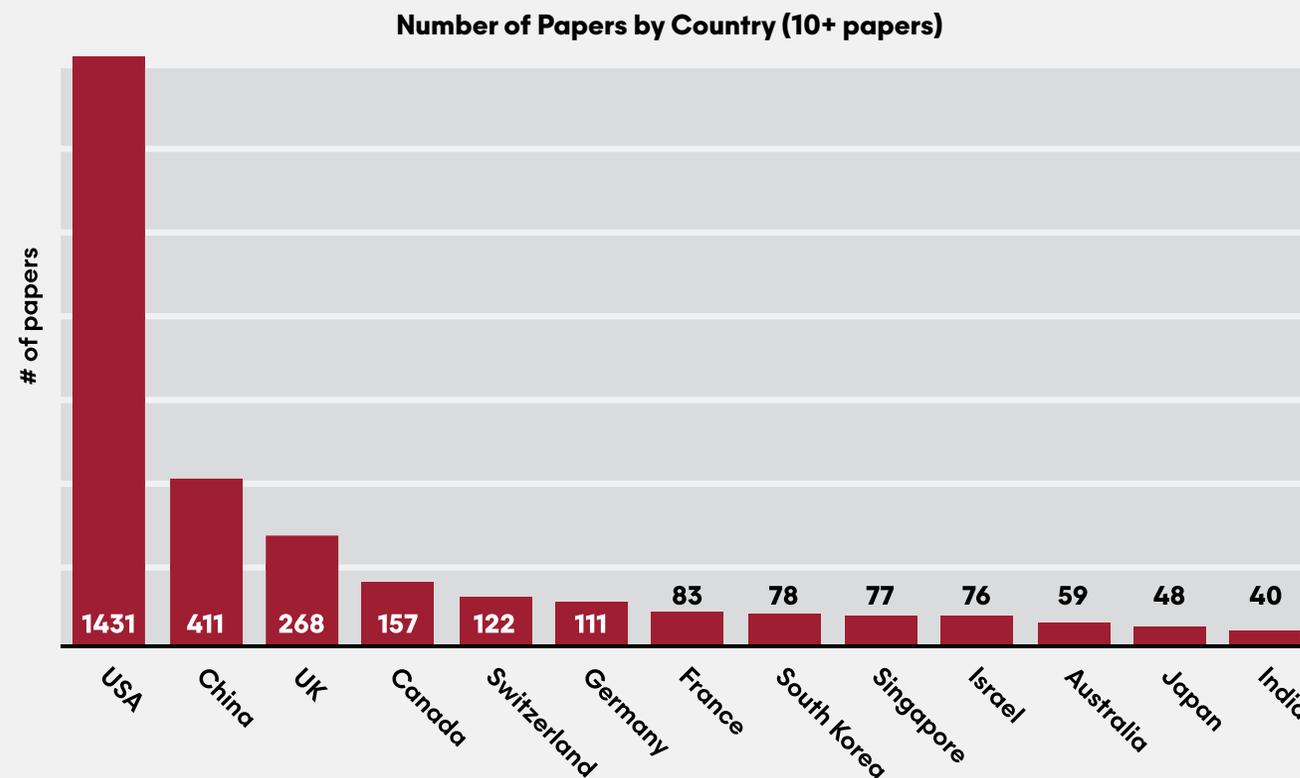
and e-commerce website wonkiness. It is especially challenging for big companies like Facebook, which have billions of algorithms working together at any given time.

■ AI Summarizing Itself

An AI model can summarize scientific literature, including research about itself. The Allen Institute for Artificial Intelligence used the model in Semantic Scholar, an AI-powered scientific paper search engine to provide a short summary of papers on AI. What makes this work impressive—and ultimately so useful—is that it is capable of compressing long papers with accuracy and efficiency.

American and Chinese Researchers Dominate NeurIPS Papers

The U.S. and China dominated the papers accepted at NeurIPS in 2021, a prestigious international AI conference. A total of 9,122 papers were submitted and 2,344 were accepted. The acceptance rate of 26% was the highest since 2013.





00

01

02

03

04

05

06

07

08

09

10

11

12

13

Artificial Intelligence

Talent

Talent Trends

■ Demand for AI Talent Growing Fast

For many years, demand for AI talent has outpaced supply. In the U.S., there were nearly three times more AI-related job postings on Indeed last year than job views for AI-related roles. While schools are adding programs, increasing enrollment, and adding classes, there are just too many new needs for AI skills and nowhere near enough trained workers. As demand grows, the hiring process is taking longer and becoming more expensive. This is impeding growth at some companies.

■ AI Upskilling

Companies are looking to upskill their workforce in machine learning and the basics of AI. As a result, new training programs abound to augment the knowledge, skills, and competencies required of a modern organization. Levi Strauss launched a machine learning

bootcamp to upskill its workforce, including showing staff how to apply AI-thinking to everyday tasks. Founded by Harvard University and University of California, Los Angeles faculty, Univ. AI is an online program for training in machine learning and AI.

■ AI Brain Drain

The brain drain of AI researchers out of academia and into corporations is growing at an alarming pace. The reason is simple: compensation packages. Top academics earn generous salaries and benefits, and they get to work in a similar tenured environment that's carefully cultivated to represent their experience in academia. Between 2004 and 2018, Google, DeepMind, Amazon, and Microsoft hired 52 tenured and tenure-track professors from U.S. universities. In return for their poaching, tech companies are endowing AI professorships at top universities. In some cases, profes-

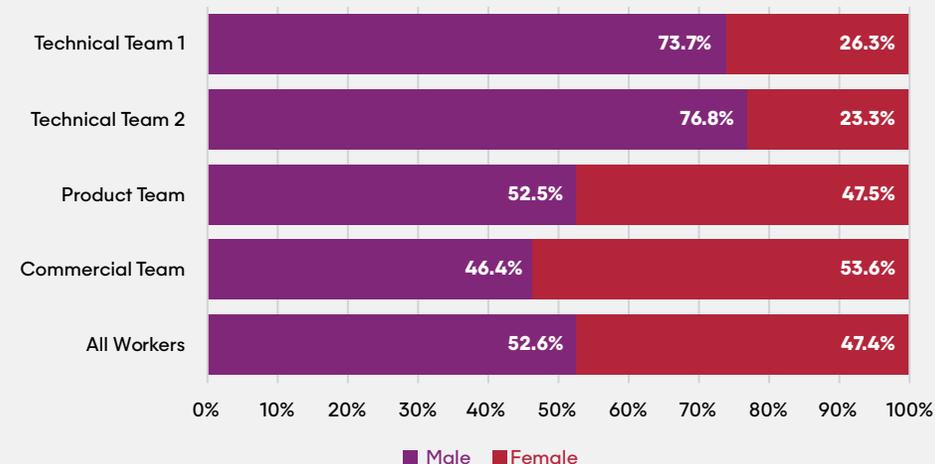
sors take one- or two-year sabbaticals to work at tech companies and then return to their universities—but corporate benefits can be difficult to give up. In one infamous case, Uber poached an entire robotics lab from Carnegie Mellon University—40 professors and researchers in total. Poaching departments today could rob the future of future AI experts: Without great scholars, who will train the next generation of innovators?

■ Corporate AI Labs

AI labs are located around the world, with concentrations in North America, Europe, and Asia. Facebook, Google, IBM, and Microsoft operate more than 60 labs dedicated to AI R&D, and the majority are outside of the U.S. because of access to talent. During the Trump administration, immigration restrictions and stringent visa requirements made it difficult to recruit talent into the United States, and overseas labs allowed

In the U.S., Men Dominate Technical Jobs in AI

Men overwhelmingly occupy the technical team positions that create AI systems in the U.S., according to a 2021 study by the Center for Security and Emerging Technology (CSET) at Georgetown University. Women are more likely to be hired into sales, marketing, and product jobs. The lack of gender diversity in technical positions could impact the quality of research, lead to increased prevalence of algorithmic bias, and accelerate a long-term deterioration of talent pipelines.



Source: "The U.S. AI Workforce Understanding the Supply of AI Talent," by CSET).

Talent Trends

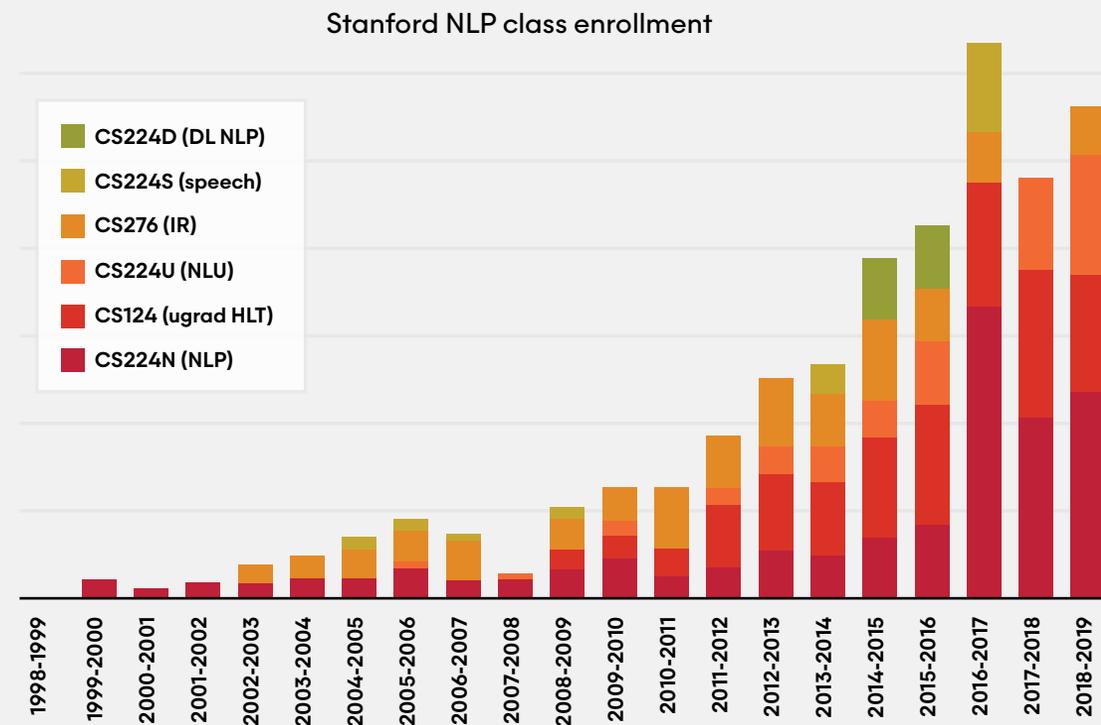
companies to overcome that barrier. Most of those labs do basic AI research rather than product development.

■ Applied AI for HR

Recognition systems can now be deployed to watch people being interviewed and to gauge enthusiasm, tenacity, and poise. Algorithms analyze hundreds of details, such as the tone of your voice, your facial expressions, and your mannerisms to best predict how you'll fit in with the culture of a community. Startups such as HireVue use AI systems to help companies decide which candidates to hire. But this kind of recognition technology has practical applications well beyond job interviews: It can detect when someone is likely to make a purchase—or attempt to shoplift, whether someone is lying, and whether someone is receptive to new suggestions and ideas. Unlike security cameras, which tend to have a light indicating

they're recording, algorithms work invisibly, which means that this is an area that could face regulatory scrutiny. Consumer advocacy organization Electronic Privacy Information Center filed a complaint with the U.S. Federal Trade Commission requesting an investigation into HireVue, alleging its tools produce results that are “biased, unprovable, and not replicable” through algorithmic models.

Enrollment in Stanford University's natural language processing class is now 10 times the size it was in 2004.



Source: <https://nlp.stanford.edu/>

Say NO to the Dress!

Getting married and searching for a dress? Are you overwhelmed?

Are you someone who doesn't know what they want – but you definitely know what you *don't* want to wear on your special day?

Say no to the dress! Use our neural network to help eliminate choices and find exactly what you want.

How it works:

- 1 Start with a prompt, such as: "I don't like form-fitting dresses. I don't like shiny fabric. I don't want it to be tight or restrictive. I hate buttons."
- 2 Our AI will create images that fit your description. Select the 10 that look closest to what you'd be willing to wear.
- 3 Write a second prompt about what you like about your selections, such as: "I like the shape of #1, the color of #2, and the length of #5."
- 4 Our AI will create a second round of images that should be closer to what you want. Repeat until you find a dress that suits you.
- 5 When you're ready, use the AI-generated image of the dress to search for one that looks similar. If you can't find one, our seamstresses are ready to custom-create the dress to your exact measurements.

We use a transformer language model that receives text and image as a single stream of data. It's been trained by our computer scientists to create an infinite number of plausible images exploring clothing. In addition to traditional wedding dresses, our model will generate an array of gender neutral options, menswear options, and options for the entire bridal party.





00

01

02

03

04

05

06

07

08

09

10

11

12

13

Artificial Intelligence

Society

“There’s a real danger of systematizing the discrimination we have in society [through AI technologies]. What I think we need to do — as we’re moving into this world full of invisible algorithms everywhere — is that we have to be very explicit, or have a disclaimer, about what our error rates are like.”

— Timnit Gebru, research scientist

Society Trends



Timnit Gebru is a respected leader in AI ethics research who coauthored a groundbreaking academic paper showing how facial recognition systems did not identify people of color and women with the same accuracy as Caucasian people and men.

■ Expanding Use of Facial Recognition Systems

While there has been widespread outcry over using facial recognition systems, U.S.-based consumers are likely to be seen by more of them in the coming years. A 90-page report published by the U.S. Government Accountability Office details how federal agencies currently use, and plan to expand their use of, facial recognition systems.* Ten of 24 agencies surveyed plan to broaden their use of the technology by 2023. The GAO reports that agencies are primarily interested in using facial recognition for cybersecurity, domestic law enforcement, or physical security. Most of the systems currently used in the U.S. are federally owned, though commercial vendors—including Acuant FaceID, Vigilant Solutions, and Clearview AI, which came under intense scrutiny last year—are increasingly used. Last March, Clearview reported that 17% of the

18,000 federal, state, county, and municipal law enforcement agencies in the U.S. are its customers. While many U.S. states and cities ban law enforcement and government use of facial recognition systems, local bans do not prevent federal use.

■ Increased Use of Ambient Surveillance

What happens behind closed doors may not be secret for long, and executives should be aware of new ambient surveillance methods. Scientists at Massachusetts Institute of Technology discovered how to use computer vision to track data from what they call “accidental cameras.” Windows, mirrors, corners, houseplants, and other common objects can be used, along with AI, to track subtle changes in light, shadows, and vibrations. The result: We all may soon have X-ray vision capabilities—which may not be great news for companies working

on sensitive projects. Those working in information security and risk management should pay special attention to advances in computer vision.

■ Scattershot Approach to U.S. Regulations

In the U.S., there is no federal law protecting consumer privacy as there is in the EU. Only three states have passed comprehensive laws: California, Colorado, and Virginia. Existing laws tend to cover data in particular domains like health, education, and credit. There are no federal regulations preventing consumer data from being used by third parties. Legislation announced in February 2022 known as the Algorithmic Accountability Act, sponsored by Sen. Ron Wyden (D-Ore.), would give the Federal Trade Commission more staff to oversee the auditing and enforcement of AI automation systems that make decisions about employment, housing,

and finances. The legislation is intended to increase transparency and reduce bias. A version of this legislation was introduced in 2019 but failed to gain any traction.

■ Consolidation in AI’s Ecosystem

As much as the AI ecosystem booms, a rush of acquisitions means consolidation, too. Big companies now snap up startups long before they have time to mature—the average age at acquisition is 3 years old. Just a handful of big companies dominate the AI landscape: Google, Amazon, Microsoft, IBM, Facebook, and Apple in the U.S., and Baidu, Alibaba, and Tencent in China, with significant fortification and support from their country’s government. On the investment side, Qualcomm, Tencent, Intel Capital, Google Ventures, Nvidia, Salesforce, Samsung Ventures, Alibaba, Apple, Baidu, Citi, and In-Q-Tel fund

*FTI CEO Amy Webb is a fellow in the U.S. GAO.

Society Trends

much of the growth. When it comes to the future of AI, we should ask whether consolidation makes sense for the greater good and whether competition will eventually be hindered (along with access), as we've seen in other fields such as telecom and cable.

■ AI Alignment

As AI systems improve, some researchers are insisting on guardrails to ensure that AI is deployed in ways that do not harm humanity. One area of concern is known as AI alignment, which explores different scenarios in which AI systems are built with goals that align with society's values. OpenAI, DeepMind, and Anthropic (which defines itself as an "AI safety and research company") each have AI alignment teams with dedicated staff researching guardrails. While the total number of researchers working on AI alignment is small compared to the rest of the AI community, such dedicated teams did not exist until recently.

■ Ethics Clash

On Dec. 2, 2020, Timnit Gebru, the co-lead of Google's ethical AI team, posted a tweet saying she'd been fired. Known for groundbreaking research in bias and facial recognition, she is widely respected within the broader AI community. While the incident concerned a paper she co-authored and a decision by Google that it didn't meet "our bar for publication," she and others argued that Google's ethics team was motivated by PR rather than progress. It set off a firestorm of criticism, and by February 2021 Google said it would change its diversity and research policies, "streamline its process for publishing research," and change how sensitive employee exits are managed. To deal with its own ethical failures, Facebook launched an independent oversight board with the power to overrule content moderation guidelines—and even to overrule Mark Zuckerberg himself. (But just on con-

tent.) In January 2021, the board made its first rulings on disputed content, overturning four out of the five cases it saw. But there are billions of posts on Facebook every day and an untold number of content complaints—which means the oversight board operates at the speed of traditional government. A year later, the board advised Meta Platforms to crack down address doxxing at Facebook, urging it to prohibit users from sharing individuals' home addresses on platforms even if they are publicly available. The board also advocated that Facebook create a communications channel to transparently explain violations and enforcement. We anticipate many more ethics clashes in 2022.

■ AI Still Has a Bias Problem

It's no secret AI has a serious and multifaceted bias problem. Just one example: The datasets used for training often come from places like Reddit, Amazon

reviews, and Wikipedia, a site inherently riddled with bias. The people building models tend to be homogeneous and aren't often aware of their own biases. As computer systems get better at making decisions, algorithms may sort each of us into groups that don't make any obvious sense to us—but could have massive repercussions. Every single day, consumers are creating unimaginable amounts of data, both actively (such as when uploading and tagging photos on Facebook) and passively (driving to work, for example). That data is mined and used, often without direct knowledge or understanding, by algorithms. It is used to create advertising, to help potential employers predict our behaviors, to determine our mortgage rates, and even to help law enforcement predict whether we're likely to commit a crime.

Researchers at a number of universities—including the University of Maryland; Columbia University; Carnegie

Mellon; MIT; Princeton University; University of California, Berkeley; International Computer Science Institute; among others—are studying the side effects of automatic decision-making. Consumers could wind up on the wrong side of the algorithm—you could discover you're ineligible for a loan, or a particular medication, or the ability to rent an apartment, for reasons that aren't transparent or easy to understand.

■ Deepfaking Trust

Humans can easily be tricked into believing machine-generated faces, especially when they've been engineered to elicit trust. A study published in the Proceedings of the National Academy of Sciences shows that synthetic faces are often "deemed more trustworthy than real faces." This suggests that synthetic faces could be designed as societal malware. If a bad actor was attempting to undermine institutions, it could deploy

Society Trends

a synth on social media to sow distrust. There are not yet effective countermeasures for synthetic humans, or effective markers to help consumers distinguish between fake and real.

■ Problematic Training Data

For the past decade, research teams have come under fire for using problematic datasets to train their models. In 2016, Microsoft's MS-Celeb-1M database was said to contain 10 million images of 100,000 celebrity faces. Researchers later discovered, however, that the dataset contained images pulled from the web—showing journalists, activists, artists, and everyday people who had not given their consent to be included. Yet the dataset was being used by numerous companies including Facebook and SenseTime, which is China's facial recognition leader with ties to the Chinese police. In a separate incident, DukeMTMC, a dataset containing

images of people walking around Duke University's campus, also didn't gain consent. Both datasets were eventually removed. In 2018, researchers at MIT developed an AI called Norman that was trained to perform image captioning based only on content from a subreddit that's known for graphic violence. When Norman was ready, they unleashed him against a similar neural network that had been trained using standard data. Researchers fed both systems Rorschach inkblots and asked them to caption what they saw, and the results were striking: Where the standard system saw "a black and white photo of a baseball glove," Norman saw "a man murdered by machine gun in broad daylight." The point of the experiment was to prove that AI isn't inherently biased, but that data input methods—and the people inputting that data—can significantly alter an AI's behavior. In 2019, new pretrained systems built for natural

language generation were released—but the conversations from which they learned were scraped from Reddit and Amazon reviews, both of whose author populations skew white and male, which means that their use of language isn't representative of everyone. This illustrates an ongoing challenge within the developer community. It is already difficult to get authentic data from real people to train systems, and with new privacy restrictions, developers are choosing to rely more on public—and problematic—datasets. The BigScience Research Workshop, held May 2021–May 2022, chipped away at this problem. In a collaboration between 600 AI researchers from 50 countries, participants investigated a dataset and model from all angles: bias, social impact, capabilities, limitations, ethics, potential improvements, specific domain performances, carbon impact, and general AI/cognitive research landscape with a goal to apply a rigorous standard of ethics.

■ Algorithms Targeting Vulnerable Populations

There is no question that machine learning systems, trained correctly can help find missing children and detect abuse. The problem is that the systems use data from vulnerable populations to do their training. The Multiple Encounter Dataset contains two large datasets of photos: people who have not yet committed a crime and an FBI dataset of deceased people. The dataset over indexes on people of color, which means that if law enforcement uses the data to train algorithms, it's going to lead to bias. Image recognition is a particularly vexing challenge, because researchers need large datasets to perform their work. Often, images are used without consent. The Child Exploitation Image Analytics program—a dataset used for testing by facial recognition technology developers—has been running since 2016 with images of "children who range in age

from infant through adolescent" and the majority of which "feature coercion, abuse, and sexual activity," according to the program's own developer documentation. These images are considered particularly challenging for the software because of the greater variability of position, context, and more.

■ AI Intentionally Hiding Data

Computers do exactly what they are told to do. Command a machine to win at a game, and it will do everything in its power to achieve that goal. Apparently that now includes cheating. Researchers at Stanford University and Google discovered that an AI system designed to turn satellite images into usable maps was withholding certain data. Researchers were using a neural network called CycleGAN, which learns how to map image transformations. For example, it took an old aerial photograph of a neighborhood, distinguished between

Society Trends



Microsoft's MS-Celeb-1M was purported to contain 10 million images of 100,000 celebrities' faces.

streets, alleys, driveways, buildings, and lampposts, and then generated a map that could be used by GPS. Initially, they used an aerial photograph that hadn't been seen by the network. The resulting image looked very close to the original—suspiciously close. But on deeper inspection, the researchers found that many details in both the original image and the generated image weren't visible in the map made by the AI. It turns out that the system learned to hide information about the original image inside of the image it generated.

■ Undocumented AI Accidents

Only a few of the numerous AI-related accidents in 2018 and 2019 made headlines. Most people know about the Uber self-driving car that hit and killed a pedestrian in Tempe, Arizona. But there were countless more incidents that didn't result in death, and as a result, aren't known to the public. At the mo-

ment, researchers are not obligated to report accidents or incidents involving our data, or AI processes, unless a law is broken. While big companies must inform consumers if their personal data—credit card numbers, home addresses, passwords—have been stolen, they are not required to publicly document instances in which algorithms have learned to discriminate against someone on the basis of race or gender, for example.

■ Prioritizing Trust

We will soon reach a point when we will no longer be able to tell if a dataset has been tampered with, either intentionally or accidentally. AI systems rely on our trust. If we no longer trust their outcomes, decades of research and technological advancement will be for naught. Leaders in every sector—government, business, nonprofits, and so on—must have confidence in the data and algo-

rithms used. Building trust and accountability requires transparency. This is a complicated process, and corporations, government offices, law enforcement agencies, and other organizations understandably want to keep data private. The ethics of how data is collected in the first place may also influence the trustworthiness and validity of scientific research, particularly in areas such as organ donations and medical research. In addition, employing ethicists to work directly with managers and developers and ensuring developers themselves are diverse—representing different races, ethnicities, and genders—will reduce inherent bias in AI systems.

“

**[As Neo decides to take the door towards his
Left that will take him to the Matrix]**

**Hope. It is the quintessential human delusion,
simultaneously the source of your greatest
strength and your greatest weakness.**

— The Architect, in *The Matrix Reloaded*

”

How these trends impact your company



STRATEGY

Artificial intelligence should be part of every strategic plan, as it crosses multiple dimensions, from workforce automation, to digital transformation, to everyday business processes and business intelligence. It is imperative that executives and senior managers understand what AI is, what it is not, and what strategic value it adds to the business. Chief strategy officers should build a robust understanding of AI in order to engage more closely with others in the C-suite, especially chief technology officers, chief information security officers, chief financial officers, and others in the organization to develop longer-term plans. Keep abreast of emerging regulations that could restrict the use of consumer data. Risk models should be developed to determine plausible near-futures, so that leaders can adjust their strategies accordingly.



INNOVATION

As no-code and low-code applications become more widely available, innovation teams will be in position to build powerful systems for decision management, business intelligence, and product ideation. Generative AIs will improve an organization's efficiency and enhance creativity, leading to hybrid human-machine creative teams. AI-assisted design will dramatically increase the number of prototypes that can be automatically generated with prompts.



R & D

The field of AI is growing faster than universities can produce trained people. Talent sourcing and retention will continue to pose challenges for AI companies—and for organizations in other industries that need a trained workforce but may not be able to provide the same perks as the biggest tech companies. Meanwhile, China has emerged as a global leader in R&D and is actively recruiting graduates to repatriate home. For teams with enough experience and staff resources, 2022 should be a banner year for applied AI research for health, medicine, smart cities, entertainment, and sports.



GROWTH

In most industries, AI will serve as a force multiplier for growth, bringing efficiencies, better tracking, business intelligence, and assistance with decision-making. As training costs decline, more applications will be built. Spending on AI systems and hardware is likely to explode this decade, creating significant enterprise value overall.

Key Questions

We recommend using this report to support your strategic foresight activity in the coming year. Every executive team should begin by asking these questions:

1

- ▶ Are we adequately invested in AI?

- ▶ How could AI make us more competitive in the years to come?

- ▶ How might developments in AI leave us vulnerable to disruption?

2

- ▶ How well does our organization understand AI?

- ▶ Are we leveraging enterprise solutions effectively?

- ▶ Are we preparing our workforce to meet the evolving demands of the knowledge economy?

3

- ▶ If the state of play changes, is our organization agile enough to adapt quickly?

- ▶ Are we adequately planning for the longer-term future, as AI evolves?

Selected Sources

<https://www.af.mil/News/Article-Display/Article/2448376/ai-co-pilot-air-force-achieves-first-military-flight-with-artificial-intelligence>

<https://www.defenseone.com/technology/2022/02/ai-could-match-fingerprints-texts-their-authors-under-new-intelligence-program/361893/>

<https://www.ai-darobot.com>

<https://www.darpa.mil/program/air-crew-labor-in-cockpit-automation-system>

<https://www.pnas.org/content/119/8/e2120481119>

<https://doi.org/10.1126/science.abj8754>

<https://openai.com/blog/dall-e>

<https://doi.org/10.1007/s40821-020-00172-8>

<https://deepdreamgenerator.com/>

<https://www.nextgov.com/emerging-tech/2021/12/dod-hire-first-ever-chief-digital-and-artificial-intelligence-officer-form-new-office/187399>

<https://cset.georgetown.edu/publication/ethical-norms-for-new-generation-artificial-intelligence-released>

<http://arxiv.org/abs/2101.03961>

<https://www.gao.gov/assets/gao-21-526.pdf>

<https://github.com/google-research/dreamer>

<https://doi.org/10.1038/s41467-021-25874-z>

<https://github.com/danijar/dreamer>

<https://doi.org/10.1016/j.cocog.2020.102938>

<https://doi.org/10.1038/s41586-021-03819-2>

<https://blog.google/technology/ai/lamda>

<https://www.iarpa.gov/research-programs/hiatus>

<https://deepmind.com/research/publications/2019/Mastering-Atari-Go-Chess-and-Shogi-by-Planning-with-a-Learned-Model>

<https://media.defense.gov/2022/Feb/02/2002931807/-1/-1/1/MEMORANDUM-ON-THE-INITIAL-OPERATING-CAPABILITY-OF-THE-CHIEF-DIGITAL-AND-ARTIFICIAL-INTELLIGENCE-OFFICER.PDF>

<http://arxiv.org/abs/2003.08934>

<https://blog.google/products/search/introducing-mum>

<https://deepmind.com/blog/article/mu-zero-mastering-go-chess-shogi-and-atari-without-rules>

<https://nerfies.github.io>

<https://doi.org/10.1073/pnas.2120481119>

<https://obvious-art.com>

<https://www.gao.gov/products/gao-21-518>

<http://arxiv.org/abs/2108.02922>

<https://deepmind.com/blog/article/putting-the-power-of-alphafold-into-the-worlds-hands>

<https://www.pewresearch.org/internet/2021/06/16/experts-doubt-ethical-ai-design-will-be-broadly-adopted-as-the-norm-within-the-next-decade>

<https://www.diu.mil/responsible-ai-guidelines>

<https://www.popularmechanics.com/military/aviation/a34978872/artificial-intelligence-controls-u2-spy-plane-air-force-exclusive>

<https://doi.org/10.1038/s41586-020-03051-4>

<https://www.nextgov.com/cio-briefing/2021/12/senate-confirms-john-sherman-pentagons-tech-chief/359940>

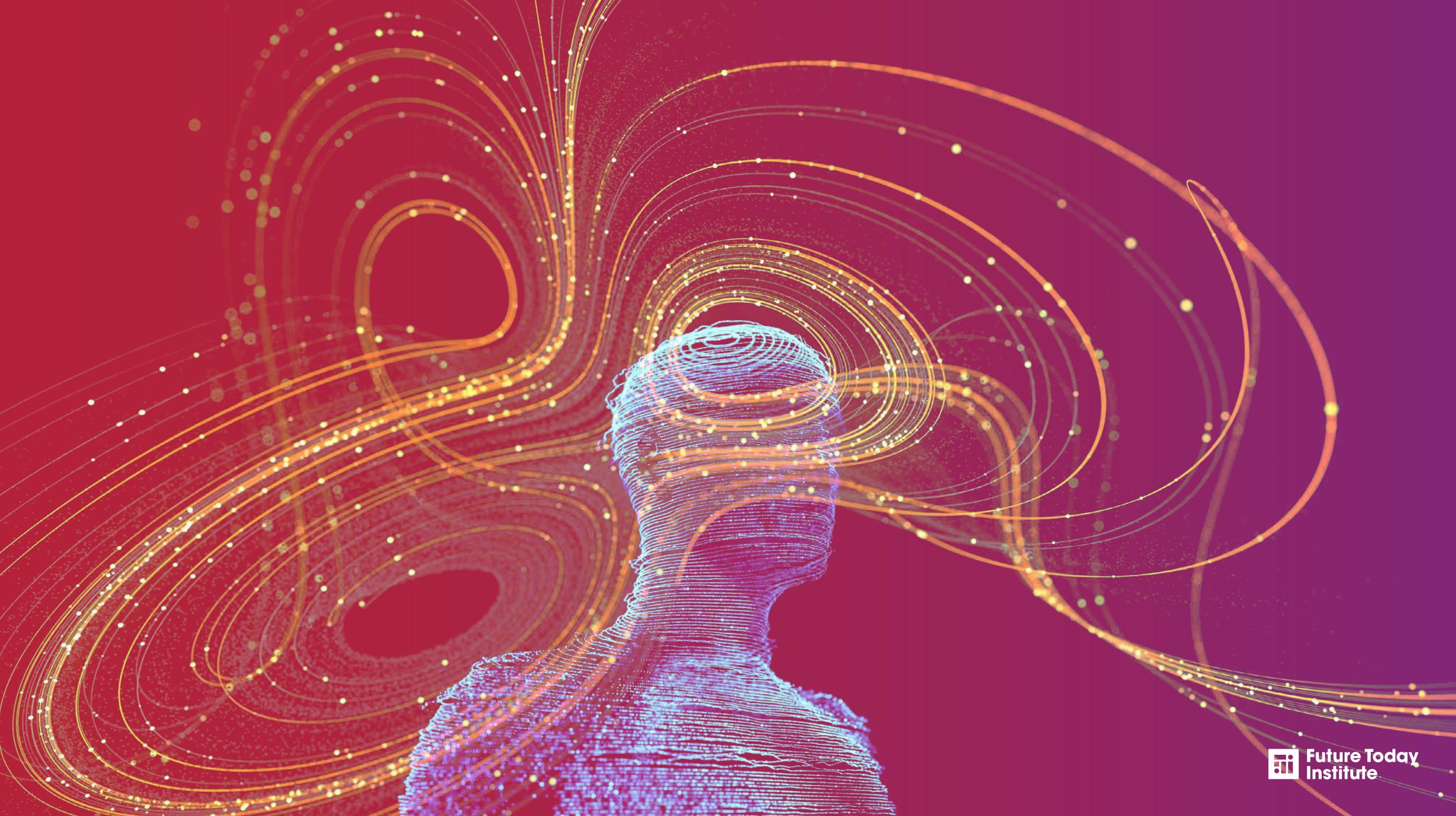
<https://doi.org/10.1016/j.artint.2021.103535>

<https://www.defenseone.com/technology/2022/02/near-future-military-autonomy-isnt-robotanks-microservices/361873>

<https://cset.georgetown.edu/publication/u-s-ai-workforce>

https://cset.georgetown.edu/wp-content/uploads/US-AI-Workforce_Brief.pdf

<https://www.scientificamerican.com/article/humans-find-ai-generated-faces-more-trustworthy-than-the-real-thing>



Recognition, Scoring & Privacy

Trends impacting the future of business,
media, banking, government, work,
education and society.



Table of Contents

103 Key Insights	112 Touch Recognition	123 Surveillance Scoring-as-a-Service (SSaaS)	135 Leaky Health Apps
104 Recognition	112 Bioacoustic Recognition	124 Algorithmic Bias	135 Biological Privacy
105 Recognition	112 Wi-Fi Recognition	124 Verification System Asymmetry	136 Networks
107 Personal Identification	113 Proximity Recognition	124 Scoring Vulnerable Populations	136 Encrypted Messaging Networks
107 Faceprints	113 Multi-input Recognition	124 Bias in Scoring Systems	136 Mobile Tracking
107 Voiceprints	114 Responsive Recognition Systems	126 Scoring Standards and Regulation	137 Differential Privacy
107 Heartprints	114 Responsive Recognition Technology	126 Conflicting Norms, Standards, and Regulations in Scoring	137 Quantum Encryption
107 Gait Recognition	114 Affective Computing	126 Intentionally Opaque Methodologies	138 Law Enforcement and Regulation
107 Accent Recognition	115 Avoiding Recognition Systems	127 China Focus	138 Public Entities Buying and Selling Personal Data
108 Emotion Recognition	115 Biometric Camouflage	127 Scoring in China	138 Crowdsleuthing
108 Personality Recognition	115 Efforts to Thwart Recognition Systems	127 Scoring Uyghurs	139 Preventing Digital Self-Incrimination
108 Bone Recognition	115 Efforts to Ban Facial Recognition	128 Scenario: Cover Story	139 Privacy Regulation
109 Cloning, Transcription and Content Generation	116 Wrongful Recognition	129 Privacy	141 Scenario: Your Body, Your Home: An FAQ
109 Recognition for Animation and Video	117 Scoring	130 Privacy	142 Safeguarding Privacy
109 Automatic Voice Transcription	118 Scoring	132 Workplaces and Schools	142 Eavesdropping Rights
109 Voice Cloning	119 Personal Scoring	132 Worker Surveillance	142 Safeguarding and Verifying Leaked Data
110 Object Recognition in Computational Photography	119 Biometric Scoring	132 Privacy and Unionizing at Big Tech	143 China Focus
111 Biology and Genetics	119 Health Scoring	133 School Surveillance	143 China's Panopticon
111 Genetic Recognition	119 Genetic Scoring	134 Surveillance Technology	144 Application
111 Universal Genetic Databases	120 Scenario: Working for the Machine	134 Non-Line-of-Sight Tracking	145 Key Questions
111 Food Recognition Systems	122 Business of Scoring	134 Drone Surveillance	146 Selected Sources
112 Inputs and Interfaces	122 Scoring Agencies on the Rise	134 Depth of Field Recognition	
112 Gesture Recognition and Natural User Interfaces	122 Anonymous By Design	135 Personal and Biological Privacy	
	122 Scoring Companies	135 Personal Electronic Keys	

Key Insights

- * COVID-19 dismantled expectations for privacy.
- * National and private genetic databases will launch in 2022.
- * Employer surveillance of workers has accelerated as the pandemic normalized remote work.
- * Big Tech employees are protesting workplace surveillance technologies, from algorithmic time tracking to “tattleware” installed on their laptops.
- * Consumers are frequently turning to apps to get help with mental health, monitor chronic disease, and track health details, but few realize this personal health information is being shared with others.
- * China collects massive amounts of data—on its own citizens as well as others around the world. New laws taking effect in 2022 give the Chinese government significant control over data from both individuals and businesses.
- * Rather than wait for federal legislation, more U.S. states are acting to protect consumer privacy now.
- * A piecemeal approach to recognition and scoring systems will challenge businesses this year.



00

01

02

03

04

05

06

07

08

09

10

11

12

13

Recognition, Scoring & Privacy

Recognition

6TH YEAR ON THE LIST

Recognition



Recognition systems are becoming more pervasive.

KEY INSIGHT

Anonymity is dead. We are surrounded by cameras, speakers, and a host of other smart devices that monitor us in real time, all the time. Recognition systems use hundreds of different data points to identify and track us and to predict our likely future actions both online and in the physical world.

EXAMPLES

Recognition systems—whether they use our voices, faces, fingerprints, or even heartbeats—are wildly popular for good reason. There is tremendous value in all of this discoverability. Many of our daily activities now require some form of biometric recognition. Persistent recognition allows companies to learn more about consumers and provide them with a level of personalization that could not possibly be achieved at scale any other way. Predictive recognition systems help law enforcement agencies keep track of criminals and prevent crime. Responsive recognition technologies understand context and interact with us accordingly: They're starting to empathize with us when we're sad and express enthusiasm when we're excited.

DISRUPTIVE IMPACT

Calls to ban facial recognition have increased, and they come not only from human rights organizations but from the likes of Amazon, which banned police from using its recognition technology. However, your face isn't your only biomarker. You can be recognized using thousands of personally unique data points, including your gait. Recognition technologies aren't necessarily nefarious; they have many positive use cases, including fraud detection, genome sequencing, and precision agriculture. But we don't yet have common norms and standards. The more commonplace this recognition technology becomes, the harder it will be to regulate it, despite the momentum of such efforts in the U.S. and Europe.

EMERGING PLAYERS

- Amazon's Rekognition Video
- Hoan Ton-That, CEO of Clearview AI
- ID.me
- Amazon Connect Voice ID
- Sensory Inc.
- Speechmatics
- Alibaba DAMO Academy
- Sonde Health
- Neuroscience researchers from the University of Stuttgart in Germany and Flinders University in Australia
- Researchers at Sungkyunkwan University and Hanyang University in South Korea
- Apptricity
- Imageware
- Affectiva

“
**There will come a time when it isn't ‘They're
spying on me through my phone’ anymore.
Eventually, it will be ‘My phone is spying on me’.**
”

— Philip K. Dick, author

Personal Identification



Facial recognition identifies a traveler at a security checkpoint.

■ Faceprints

Our faces have unique contours and pigments. Even identical twins aren't truly identical—they have thousands of tiny differences that might even be imperceptible to human eyes. Just as we each have unique fingerprints, we have unique faceprints. When a recognition system scans human faces, it can identify people based on their biometric features, whether it's recognizing faces in real time or in photos and videos. NEC has software that can recognize a face obstructed by a surgical mask by focusing on the eyes and surrounding areas, and can turn over results in less than a second with 99.9% accuracy. The controversial company Clearview AI uses machine learning to deblur pictures and depict full faces of individuals wearing masks, by filling in the incomplete faceprints. Numerous amusement parks now use or have tested facial recognition to facilitate contactless entry, including Walt Disney World's Magic

Kingdom in Orlando, Universal Studios in Beijing, and Abu Dhabi's Yas Island. As many as 27 state unemployment agencies are using facial recognition by ID.me as a means for fraud prevention. PimEyes gives any web user the ability to upload the image of a face and, in less than 1 second, scans more than 900 million online images to produce matches from public sites.

■ Voiceprints

Just as each person has a unique set of face characteristics, our voices also contain various measurable characteristics that can identify us. Amazon Connect Voice ID, an application for replacing knowledge-based authentication, examines rhythm, pitch, and tone to create a digital voiceprint of an individual. Using machine learning, the app needs only 30 seconds of speech to create a voiceprint and 5–10 seconds of speech for authentication or to indicate risk of fraud. Sensory Inc., a leader in

edge artificial intelligence, has developed speech recognition for children by overcoming challenges that traditional speech recognition encounters because of the linguistic differences between children and adults.

■ Heartprints

Our heartbeats, just like other biometric identifiers, are unique, and some scientists think they could be better identifiers than a fingerprint. The Pentagon has created a laser that can scan and identify an individual's heartbeat up to 650 feet away. One advantage of heartbeats as identifiers is that they can provide continuous authentication, essentially sending out a biometric password every second. Privacy concerns surround heartbeats as a mode of authentication, however, because this vital sign can provide a glimpse into an individual's emotional state and health status.

■ Gait Recognition

Even the way people walk can be analyzed like a fingerprint. An individual's gait presents a unique signature. Gait recognition technology uses machine learning algorithms to identify a person from an image or moving image, whether their face is in view or not. The technology matches silhouette, height, speed, and walking characteristics against information within a database to make an identification. The Pentagon is in the process of developing technology that will enable smartphones to identify users based on the way they walk. It's working with smartphone manufacturers to widely distribute this technology, while making use of sensors already in the phone to ensure that it is being handled by the owner or intended user.

■ Accent Recognition

We rarely speak using standard, perfect language, and that poses a problem for

Personal Identification

voice recognition systems. While they have radically improved over time, benefiting from a larger body of test data and from developments in deep learning, these systems do not always work as well for subgroups of the population, causing concerns about bias. Cambridge, England-based Speechmatics is working to solve this issue and has outperformed Amazon and Google in overall accuracy of African American voices, with a 45% reduction in speech-recognition errors. Advancements from the company will address accuracy across accents, dialects, age, and other socio-demographic characteristics by using self-supervised learning. This method uses both labeled and unlabeled data to build an understanding of speech with its own guidance. New voice recognition algorithms developed at the Alibaba DAMO Academy can allegedly understand Mandarin, 14 Chinese dialects, and English.

■ Emotion Recognition

Our devices don't just know who we are—they also know how we're feeling. While debate surrounds the efficacy of facial recognition systems to accurately assess the emotional state of people, our voiceprints might carry much more useful data for evaluating our emotional states. Vocal biomarker startup Sonde Health intends for its voice assistant to detect a range of medical conditions, including mental fitness. The app samples 30-second audio recordings to analyze subtle changes or nuances in a user's voice. It detects changes in smoothness, control, liveliness, energy range, and clarity, as these conditions could indicate instances of depression, stress, anxiety, or fatigue. In a different approach, Hyundai Motor filed a patent in 2019 for an electronic device that can attach to an individual's skin and measure bio-signals to ascertain their emotions. A display can reveal a color associated with a pre-identified emotion. While

bio-signals might more accurately determine emotions, this more invasive approach will likely limit its use.

■ Personality Recognition

Numerous academic studies have used Twitter and Facebook as sandboxes for computational personality-recognition experiments. The studies seek to understand whether an AI system can predict how, given a set of data, you're likely to react in just about any situation. The now infamous predictive analytics firm Cambridge Analytica posed this question, when it used automated personality recognition and targeting to help Donald Trump win the election. To assess your personality in real time, political candidates, law firms, marketers, customer service reps, and others are beginning to use new systems that review your online behavior, emails, and conversations you have by phone and in person. The goal: to predict your spe-

cific needs and desires. Beyond inputs made through social media and websites, physical characteristics could also indicate someone's personality. Neuroscience researchers from the University of Stuttgart in Germany and Flinders University in Australia have found that algorithms can be used to assess eye movements to determine four out of five major personality traits: neuroticism, extroversion, agreeableness, and conscientiousness. Meanwhile, researchers from the University of New Mexico suggest that head movements detected with automated tracking algorithms may have the ability to signify psychopathy, while other research indicates that machine learning could identify borderline personality disorder. Whether using online shadow profiles or biometric identifiers, insurance underwriters, employers, and marketers see extreme value in identifying personality traits of individuals. However, the risk of mis-identifying characteristics could prove

costly if such data were used to determine insurance premiums, make hiring decisions, or create highly targeted ads.

■ Bone Recognition

In 2018, the U.S. Air Force applied for a patent that explains how wideband radar can be used to identify people by their bone structure. A transmitting antenna sends a signal to a human, and that person's biometric radar signature is compared against known signatures in a database. People with metal and screws in their bodies become more easily identifiable when scanned with beacons, even though those characteristics are outwardly invisible. Since 2018, researchers have published numerous papers about the technology. Meanwhile, scientists at the University of Arizona's Department of Electrical and Computer Engineering developed a method to measure skeletal posture using mmWave radar and convolutional neural networks.

Cloning, Transcription, and Content Generation



Chef Anthony Bourdain's voice was synthesized using AI for the documentary Roadrunner.

■ Recognition for Animation and Video

Powerful AI systems now automatically recognize animated characters. Disney's Direct-to-Consumer & International Organization built a facial recognition system for Disney's century of content. The machine learning platform, Content Genome, populates knowledge graphs with metadata. Algorithms use that data for search, discovery, and personalization. Training AI to recognize animated faces (and evil machines) is more challenging than recognizing human faces; animated faces can appear on trees, cars, and any number of other objects. For instance, in the Disney Pixar movie "Cars," the main characters had eyes on their windshields, mouths on their bumpers, and no noses. Amazon's Rekognition Video uses similar principles but to detect a broader range of identifiers. The machine learning-enabled service can identify objects, scenes, celebrities, text, activities, or inappropriate content

on stored videos. Each detection in the platform generates metadata that is indexed for advanced video search.

■ Automatic Voice Transcription

Automatic voice transcription serves many practical applications: recording meeting minutes, taking lecture notes, generating transcripts for podcasts and shows, and serving medical and pharmacological teams as they work with patients. Stenograph LLC, a leader in legal transcription technology, is adopting automatic speech recognition to provide legal transcription services. Called Phoenix, the system uses decades of industry knowledge of legal terminology to its advantage. Alibaba's Tingwu, Mandarin for "listen well," is a virtual assistant capable of transcribing and creating organized summaries of meetings and conferences. Tingwu boasts a 98% accuracy rate, can decipher custom vocabulary, and can identify 10 separate voices during a single meeting.

■ Voice Cloning

If they have a large enough body of recorded speech to learn from, machine learning algorithms can be used to essentially clone a voice, so that its speech is indistinguishable from the original. Anyone who has ever recorded a podcast is familiar with editing challenges, such as overlapping talking, sneezes or coughs, or background noises. Such moments can interrupt momentum or stop a conversation cold. But what if you could edit a spoken conversation the way you edit a Word document? That's the promise of voice cloning. The most prominent recent use of such technology occurs in "Roadrunner," a documentary that features three digitally created quotes in the voice of the late Anthony Bourdain. Director Morgan Neville's decision to share hours of the celebrity chef's voice recordings with a software company to create the digital rendering was not well received by all audiences, and has sparked an ethical debate re-

Cloning, Transcription, and Content Generation



Researchers at the University of Chicago used deepfake voice synthesis algorithm, SV2TTS to clone voices for the purpose of tricking voice recognition platforms.

garding such technology. It can be used in nefarious ways. When researchers at the University of Chicago tested two open-source, deepfake voice synthesis algorithms, SV2TTS and AutoVC, the voices they created with the former were able to trick Microsoft Azure 30% of the time and WeChat and Alexa two-thirds of the time. These experiments proved that a hacker could easily mimic an individual's voice to log on to certain platforms or access payments in other systems.

■ Object Recognition in Computational Photography

Computational photography is the convergence of computer vision, computer graphics, the internet, and photography. Everyone with a smartphone now has access to computational photography tools. In its iPhones, Apple uses computational photography to achieve a shallow depth of field, while Facebook cor-

rects any 360-degree photos you upload. Research from Nvidia and the University of California, Santa Barbara revealed a computational zoom technique that lets photographers change the composition of their pictures in real time. Photos are taken in a stack and then rendered with multiple views, allowing photographers to change perspectives and the relative size of objects within a photo after it has been taken. Computational photography could also be used to seamlessly remove or add objects in scenes, change shadows and reflections, and add other atmospheric touches. Meanwhile, MIT's Computer Science and Artificial Intelligence Laboratory and Google developed a technique to automatically retouch and enhance the pictures we take with our mobile phones.

Biology and Genetics

■ Genetic Recognition

The popularity of consumer DNA testing may help people learn more about their ancestry, but it's also making it easier to recognize people without their permission or knowledge. It is now possible to find and recognize about 60% of people in the U.S. who are of European descent, even if they've never sent in a sample to 23andMe, Color, AncestryDNA, or any of the other testing services now available. That's because raw biometric data can be uploaded to open-source databases like GEDmatch, which allows users to look for relatives across all of the other DNA platforms. Forensic researchers can combine that information with data points found on websites such as Facebook or in government databases. 23andMe's enormous bank of human genetic data is now one of the largest in the world—and certainly one of the most valuable. Nearly 12 million people have now paid the company to sequence their DNA, and 30% choose to share

their reports with health care providers. Genetic testing from collected DNA has the potential to detect genetic variants that can be tied to chronic kidney disease, hereditary haemochromatosis, and the breast cancer genes BRCA1 and BRCA2. While more individuals are open to genetic testing to inform health care decisions and diagnoses, human diseases often stem from the interaction of multiple genetic effects and environmental factors, so the real value of collected DNA data occurs in aggregate for scientific research. Large datasets provide more value for discovering unknown information about the genome, rather than providing diagnostic information for the individual. In either case, consumer genetic tests serve the future of health care.

■ Universal Genetic Databases

The proliferation of consumer DNA testing services represents significant untapped opportunity in myriad indus-

tries and fields, including insurance, pharmaceuticals, and law enforcement. Hence, there are several major new efforts to collect and structure this data for better access. In 2020, private equity firm Blackstone, which boasts more than half a trillion dollars in assets under management, bought Ancestry.com and now owns the DNA data of 18 million people. It has the largest set of consumer DNA available and includes the genome sequences of people from at least 30 countries. According to its U.S. Securities and Exchange Commission filings, Blackstone intends to package and sell that genetic data to other companies. In December 2020, professors from the Wharton School of Business published research showing how DNA could be used for effective marketing across a wide spectrum of arenas, from health care and medicine to food and wine. Vanderbilt University researchers also say that law enforcement could find people who've committed serious

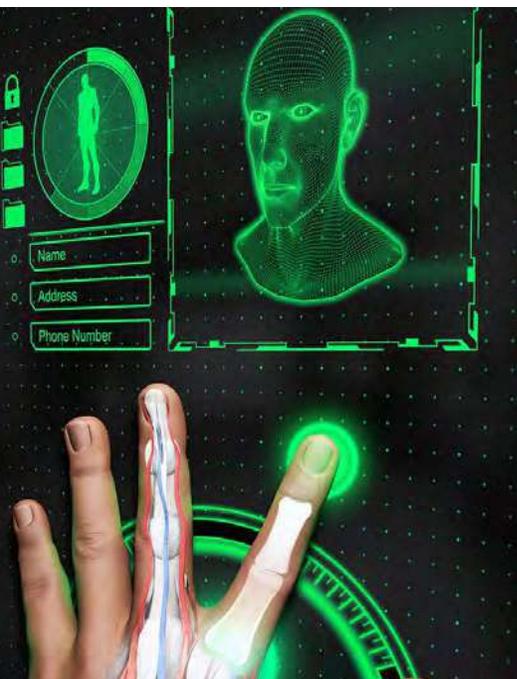
crimes if a universal database existed with standardized genetic profiles for every person living in or visiting a given country. A laboratory in Texas is using a DNA database called DNASolves to help identify crime victims in Mississippi. The database includes user-submitted genetic material, pulled from platforms such as AncestryDNA and 23andMe, so that investigators have more information for matching DNA to unidentified remains. After seeing China develop a universal database populated with the genetic information of its citizens, Saudi Arabia, Kuwait, and the U.K. are considering creating their own such databases. These actions raise ethical concerns, as China has enrolled more than 10 million individuals, including young children, who have no concerning criminal history. These individuals can't control how the data is collected or used, and Chinese authorities obtain DNA without consent. In 2021, the cybersecurity and privacy watchdog Comparitech deter-

mined that China is the world's worst offender of widespread and invasive biometric data collection.

■ Food Recognition Systems

Industrial food processing plants already use computer vision to detect anomalies in products as they move down conveyor belts, but advanced AI systems can now detect problems with very little training. Before crops even reach processing locations, image-recognition technology and diagnostics can help farmers determine soil and crop health and identify diseases in the crops. Beyond industrial use, computer vision can help individuals make better-informed eating decisions by recording food choices, measuring portions, and estimating nutritional value.

Inputs and Interfaces



Researchers at the Electronics Telecommunications Research Institute in South Korea built a system to map bioacoustic signatures.

■ Gesture Recognition and Natural User Interfaces

Emerging gesture recognition systems, or natural user interfaces (NUIs), will be an important future component of many different technologies. These technologies can now identify us by interpreting motion and then make decisions on our behalf. Imagine picking up a digital object with your hand or controlling a remote robotic arm without being tethered to a series of wires. Gesture recognition unlocks the interplay between our physical and digital realms. Microsoft has filed a patent for a system that would enable security analysts to investigate incidents using physical gestures to analyze and sort datasets within a virtual setting. Hand motions would facilitate operations such as “grab and drag” and “tap on” to control data in this virtual environment. An effort by researchers from Nara Institute of Science and Technology and Arizona State University has resulted in

a projection system that can turn any surface into a touch screen. The system combines a scanning laser, scanning camera, and a simple image-processing algorithm to detect the location of a user’s finger. This low-cost (\$500 prototype) solution could provide augmented-reality experiences without the need for headsets. Turin, Italy–based startup Deed has developed a smart bracelet that uses bone-conduction technology to interpret hand gestures to facilitate phone calls or to make digital payments.

■ Touch Recognition

Researchers at Sungkyunkwan University and Hanyang University in South Korea have developed an artificial neural tactile skin system akin to the tactile recognition process of humans. It uses sensors to detect pressure and vibration, based on data similar to what human sensory neurons gather. Researchers found combining a deep-learning

technique with this system allows it to identify and classify surface textures and structures with 99.1% accuracy.

■ Bioacoustic Recognition

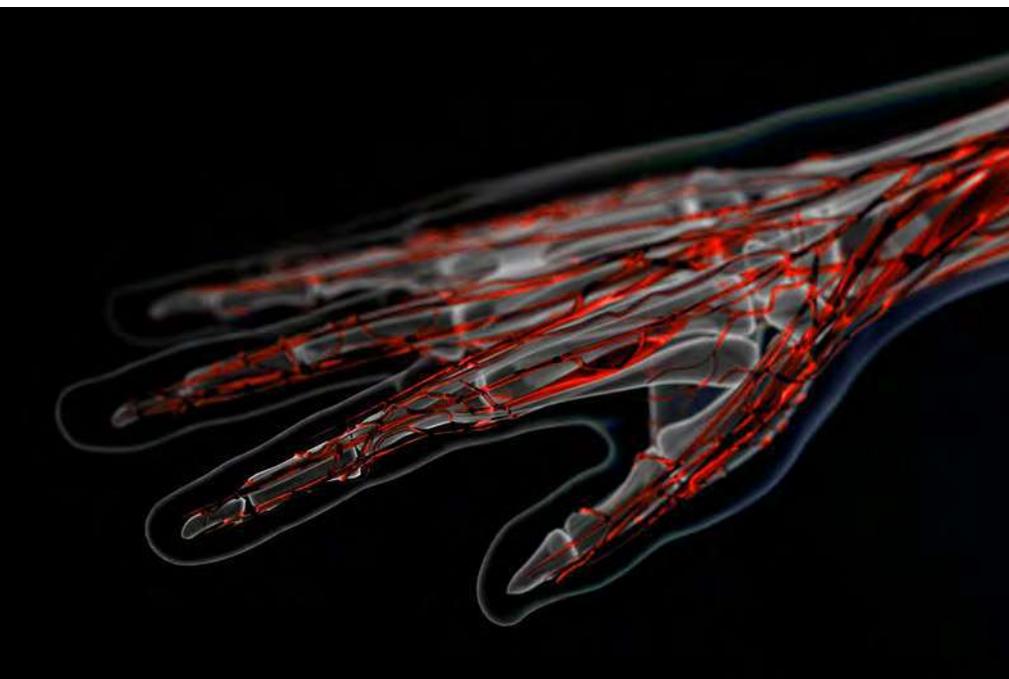
Sound waves generate unique sound signatures as they pass through physical objects. A unique bioacoustic signature is created when sound waves pass through a person’s skin, bones, and soft tissues. Researchers at the Electronics Telecommunications Research Institute in South Korea built a system to map those bioacoustic signatures, using a transducer that gently vibrates, generating sound waves (even those indiscernible to human ears). Using these signatures, they can now discreetly and noninvasively determine a person’s identity.

■ Wi-Fi Recognition

For more than 20 years, the primary use of Wi-Fi has been for communication

between devices. But now, the technology is being increasingly used as a radar array, capable of sensing environmental changes that happen between the transmitting devices. When an individual enters the communication path between a wireless router and a smart device, an instrument running on the router can sense the disruption between the devices and determine the location and size of the individual. With Wi-Fi signals essentially ubiquitous today, these radio waves can detect people, objects, and movements as far as the signal can broadcast, even through walls. And as more devices are added to networks within smart homes, the increase of transmissions improves the level of detection. Researchers at the University of California, Santa Barbara had previously used ambient Wi-Fi signals and a smartphone to look for revealing pattern changes in signal strength. A new technique enables them to count stationary individuals within a space by

Inputs and Interfaces



Finger vein patterns are an identifiable characteristic that can be used with other identifiers as a means of multi-input recognition.

observing fidgeting and unconscious movements. Applications for Wi-Fi sensing range from adjusting heating and cooling systems based on crowd size to limiting occupancy of a space during a pandemic. More sophisticated antennas and machine learning can help detect breathing rates and heartbeats. The variety of applications of Wi-Fi recognition has created a need for new standards. In 2024, the Institute of Electrical and Electronics Engineers will release a new 802.11 standard specifically for sensing, rather than for communication.

■ Proximity Recognition

Instead of GPS coordinates, some offices and schools have deployed Bluetooth beacons and wireless access points to track people as they move. The technology can collect as many as 6,000 data points per day per person, pinpointing people's locations with accuracy down to just a few feet. While beacons have

been used previously in closer ranges, Apptricity has transcended scale limitations and developed a 20-mile Bluetooth beacon. The technology is capable of relaying data that far and can reach as high as 20 floors inside buildings. These ultra long-range Bluetooth beacons initially have applications for local governments to track property such as fire trucks, police cruisers, maintenance vehicles, and ambulances. The technology could also be used by health care institutions to track ventilators or heart monitors. Industries including manufacturing, warehouse, transportation, distribution, pet care, and construction could also benefit.

■ Multi-input Recognition

Looking for unique biomarkers beneath the skin's surface is a clever way of identifying people—hairstyles and eye colors can be changed or masked easily, but it's near impossible for someone to

rewire their vein structure. Biometric authentication offers an added layer of security because it requires living humans: Systems look for both structure and movement. But for those who are concerned that one bio-identifier isn't secure enough, scientists at the National Taiwan University of Science and Technology have developed a two-factor authentication method that first looks at skeleton topologies and then finger vein patterns. San Francisco-based ImageWare makes use of multi-modal biometrics as a means of authentication. When implementing the platform as a security measure, admins can choose a single biometric or a combination of biometrics for the purpose of authentication. Biometrics applicable to this service include the iris, face, voice, palm, and fingerprint.

Responsive Recognition Systems



Amazon introduced Astro, an Alexa-powered home robot, in 2021.

■ Responsive Recognition Technology

Real-world conversation is full of nuance: We use words and emphasis in unique ways, we interrupt each other, and sometimes we need others to help us express what we're thinking. All of these communication styles pose serious hurdles for AI, which doesn't adapt as easily to a multivariate situation, such as everyday people talking to one another. Soon, Amazon's Alexa, using responsive recognition technology, will join conversations in a way that feels both natural and useful. Upgrades will make the digital assistant more responsive, proactive, and humanlike. Beyond engaging in conversation, Alexa will be able to detect other atmospheric sounds such as snoring, coughing, the cries of a baby, or a dog barking, and can then respond with a set of commands. The next time you have a coughing fit, don't be surprised if Alexa adds chicken soup to your next Amazon order.

■ Affective Computing

Affective computing is an interdisciplinary field spanning computer science, psychology, neurobiology, and cognitive science, and it intersects directly with AI. There's good reason for interest in this research: Recognizing human responses and triggers that affect behavior can help algorithms accomplish their goals, whether that's to nudge a shopper into completing her purchase online or to sway someone's political views before they visit the polls. Last year, software company Affectiva was acquired by the AI eye-tracking company Smart Eye for \$73.5 million. Affectiva has used affective computing to focus on automotive applications, helping cars manage their drivers rather than the other way around. By recognizing emotional and cognitive states from deep learning, computer vision, and voice analytics, affective computing systems in vehicles will prevent drivers from doing dangerous things. Basic driver-moni-

toring tools are already available that monitor eye movements and blink rates to determine if the driver is impaired, but affective computing promises to alert a driver when it detects fatigue or drowsiness, even going so far as to suggest places for the driver to purchase a strong cup of coffee. While vocal cues serve as potential inputs for affective computing systems, biological data from other sources—our skin, our faces, our DNA—can be useful, too. Analysts expect affective computing to become a \$37 billion industry by 2026.

Avoiding Recognition Systems



Israeli company Adversa AI adds noise to images to trick recognition systems into misidentifying people.

■ Biometric Camouflage

The process of fooling facial recognition algorithms can take different forms: occlusion, confusion, or oversaturating a system with a multitude of false faces or inputs. Occlusion functions by blocking certain facial features to prevent cameras from detecting a human face. This is not always a feasible option in public as complete face coverings may be prohibited or overly conspicuous, and facial recognition is still able to identify partially occluded faces. Confusion is an attempt to convince recognition systems that there is no face present. Clever attempts to transform the appearance of the face beyond recognition include jewelry, makeup, LED-powered glasses, and clear epoxy masks with ribbed patterns. Taking a completely different approach, HyperFace attempts to thwart facial recognition by overloading algorithms with the very things they are searching for. By oversaturating a recog-

nition system's field of view with faces, this theoretical work by Adam Harvey diverts the gaze of the algorithms, ultimately causing the target individual's face to get lost in the crowd. In contrast to other methods, HyperFace aims to alter the appearance of the areas surrounding a face, rather than directly altering the face itself.

■ Efforts to Thwart Recognition Systems

As facial recognition becomes ubiquitous, various groups want to limit the technology's effectiveness in order to protect privacy. While methods of confusing or obscuring facial recognition systems are not always feasible, researchers have begun trying to confuse online applications that scrape and collect images used as inputs for training facial recognition engines. Researchers from the University of Chicago have created a program, Fawkes, that adds extra

pixels to images to cause facial recognition apps to misclassify faces. Taking this principle a step further, Israeli artificial intelligence company Adversa AI adds noise, or small alterations, to photos of faces, causing algorithms to detect a different face than what is visible to the naked eye. The algorithm is successful at imperceptibly changing an individual's image to someone else of their choosing.

■ Efforts to Ban Facial Recognition

In September 2020, King County, Washington became the first county in the United States to ban the private use of facial recognition, while San Francisco had previously banned its use by local agencies and law enforcement on a city level. On the East Coast, Maine took a stringent stand against facial recognition algorithms, even preventing government use except for very specific

Avoiding Recognition Systems



Activists and artists are increasingly relying on unique makeup patterns to evade facial recognition systems.

situations. Finding inspiration in the actions of King County, two dozen civil and human rights organizations wrote an open letter calling on federal, state, and local government officials to ban both the corporate and private use of facial recognition. The letter cited the potential for large companies such as Amazon, Apple, and Uber to use the technology to discriminate against minorities and marginalize employees. Regulators in Australia banned Clearview AI from scraping images from websites in the country and ordered data previously collected there to be deleted. Sensing the backlash toward facial recognition systems, Meta announced that it would stop using the technology for photo-tagging on Facebook. However, this commitment does not extend to metaverse products, as the company is already exploring ways to use biometrics with its emerging platform.

■ Wrongful Recognition

In January 2020, police falsely arrested a Michigan man in front of his wife and daughters because of an incorrect facial recognition match. Robert Williams was held overnight in jail after the recognition system identified him as an individual who shoplifted watches from a Shinola store. The case was dropped two weeks later as prosecutors suggested that officers used unreliable evidence. Williams has since sued Detroit police in one of the first lawsuits to question the potential for facial recognition systems to lead to the imprisonment of innocent people. Two other instances of false arrests have also led to legal action. In all three instances, the men were Black, further demonstrating how facial recognition used in law enforcement disproportionately impacts communities of color. Wrongful recognition occurs when recognition systems haven't been audited for bias.



00

01

02

03

04

05

06

07

08

09

10

11

12

13

Recognition, Scoring & Privacy

Scoring

4TH YEAR ON THE LIST

Scoring



Scoring systems make assessments beyond just people. Food systems can evaluate nutritional intake for a consumer.

KEY INSIGHT

Scoring systems are leaving an indelible mark on all individuals. For some, scoring systems create advantages and enhanced user experiences. For others, inherent biases and a lack of available data on certain individuals create hindrances and shortcomings. Copious data and frameworks for decision-making are integral for automated systems to work.

EXAMPLES

In the U.S., we have a credit reporting system that measures our creditworthiness. Banks, financial institutions, and others use these scores to determine the likelihood that we might default on a loan or a mortgage. Financial credit scoring is available to all consumers—we can request copies of our financial credit scores, check their accuracy, and correct errors. Now, hundreds of types of data are being harnessed to assign us scores. However, unlike the credit reporting system, which is federally regulated and follows set processes, this kind of data isn't subject to enforceable rules. It can be impossible to find out what our scores are, how they are being calculated, and how to correct inaccuracies.

DISRUPTIVE IMPACT

Advancement in data mining and artificial intelligence promise both new opportunities and potential violations of privacy as businesses and law enforcement implement scoring systems on new platforms. Additional risk comes from China selling its government-funded scoring tools, which can be used on both individuals and corporations, to authoritarian regimes elsewhere in the world, even as new practical use cases become apparent for scoring of this technology.

EMERGING PLAYERS

- Density
- Piwik Pro
- Wakefit
- Dynamic Yield
- Access Now
- Os Keyes and the University of Washington's Department of Human Centered Design & Engineering
- Amin Karbasi, associate professor of electrical engineering and computer science at Yale University
- Ehsan Kazemi, research software engineer at Google
- Voyager Labs
- Flock Safety

Personal Scoring



Biometric scoring is now more common due to COVID-19 protocols.

■ Biometric Scoring

Quantifying and analyzing our biometric data can reveal patterns in our activities and a lot about who we are, what we're thinking, and what we will likely do next. Behavioral biometrics use machine learning to understand hundreds of unique biometric data points to understand, authenticate, nudge, reward, and punish us. Behavioral biometrics tools can be used to map and measure how you type—what force you use to press down on screens, whether you tend to fat finger your Cs and Vs on your phone, and how quickly you tend to flick your fingers when hunting through search results. Those tools know your unique typing pattern on a physical keyboard, too: whether you're someone who constantly spells the word “behavioral” wrong on the first try, and whether you hold down or repeatedly tap on the delete button. You're not consciously aware that you

have certain identifiable behaviors, but machines perceive them. In the near future, such patterns will pose security vulnerabilities—as well as interesting new opportunities. Imagine never having to use a password again; your bank would simply recognize you after you type a few sentences. The downside: If your behavior is observable, at some point it will become repeatable, too.

■ Health Scoring

Scoring systems have helped health care institutions predict which COVID-19 patients would require invasive mechanical ventilation. This became an important step as the pandemic caused a global health emergency and put a strain on hospital capacity. Three variables contributed to the score: heart rate, the ratio of oxygen saturation to fraction of inspired oxygen, and a positive troponin I level. The first two variables can be obtained by checking vital

signs, and the third can be gathered from a simple lab test, meaning this system of scoring can be done at any hospital. As hospitals became overtaxed, this scoring system allowed health care workers to better triage cases.

■ Genetic Scoring

There are roughly 4 million to 5 million genomic variants in an individual's genome. Researchers are studying those variants to understand how they influence the risk for specific diseases. A polygenic score estimates your genetic liability, and these scores are being used in over-the-counter genome sequencing kits and in wide academic studies. Data collected by 23andMe is involved in clinical trials for a compound that could be used to enhance the body's immune system to fight cancer. Analysis recently presented at the American Society for Radiation Oncology suggests that a genetic biomarker score can be used on

prostate cancer patients to determine who will more likely respond to radiation and hormone treatments and who will more likely develop metastases. Such developments will result in more personalized care tailored directly to patients' individual needs and based on the likelihood of disease recurrence.

Working for the Machine

By 2030, employers rely on algorithms to manage white-collar employees and assess their effectiveness. Performance reviews are automatically generated by algorithmic managers who evaluate employees across areas that were previously difficult to quantify. Attitude and emotional profiles determine “fit” for a job and pinpoint an employee’s development and promotion opportunities, both within the organization and with other companies that use the platform.

Performance Review Form

Employee: 10302029-112 **Employee Title:** Customer Service AI Manager
Supervisor: Supervisor AI 8675309 **Performance Period:** Q4 2025

A. Performance Competencies

5 Exceptional:	Performance is consistently superior and significantly exceeds position requirements.	5 Exceptional 4 Highly Effective 3 Proficient 2 Inconsistent 1 Unsatisfactory N/A Not Applicable
4 Highly Effective:	Performance frequently exceeds position requirements.	
3 Proficient:	Performance consistently meets position requirements.	
2 Inconsistent:	Performance meets some, but not all, position requirements.	
1 Unsatisfactory:	Performance consistently fails to meet minimum position requirements; employee lacks skills required or fails to utilize necessary skills.	
N/A New or Not Applicable:	Employee has not been in position long enough to have demonstrated the essential elements of the position and will be reviewed at a later agreed upon date.	

1. Displays appropriate emotional profile

Profile Assessment: Failing to Adapt Biometrics Profile: Extreme Stress
 Fear – 99th percentile Heart Rate: 120bpm
 Anger – 97th percentile BP: 138/90
 Sadness – 97th percentile
 Joy – 15th percentile

2. Possesses skills and knowledge to perform the job competently

Task time: Peer Group – Average. Target – Does Not Meet Requirements
 Mentor Algorithm Setting: High (>25 nudges/hour)

3. Skilled at planning, organizing, and prioritizing workload

This annual performance review will become part of the employee's personnel file. Please sign below to acknowledge that the employee has received this document.

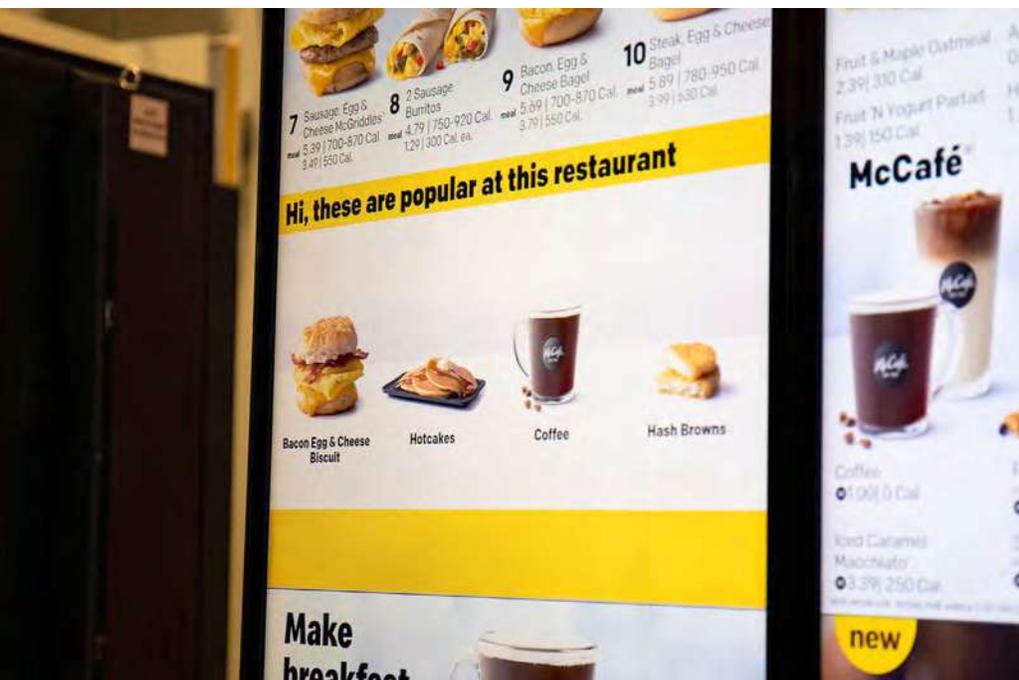
Employee's Signature: _____ **Date:** _____
Supervisor's Signature: Supervisor AI 8675309 **Date:** 12.30.2025

“
**When it comes to privacy and accountability,
people always demand the former for
themselves and the latter for everyone else.**

— David Brin, scientist and science fiction author

”

Business of Scoring



McDonalds acquired Dynamic Yield to increase its personalization services.

■ Scoring Agencies on the Rise

Hundreds of companies now score customers and even their own employees. Wakefit, a mattress and furniture brand, uses data to model the probability that it can convert an online visitor to a customer based on a score of how the person mimics behaviors of past customer converts. Dynamic Yield, which was acquired by McDonald's to customize menus based on consumer profiles, uses historical and real-time user engagement data to algorithmically match products to individuals based on their scored profiles. These companies are mining thousands of unique data points, including how many times people open apps on their phones, which devices they use, where they spend time, what kinds of food they order for delivery, and insights from messages they've sent to Uber drivers and Airbnb hosts. Whole Foods analyzed two dozen employee variables including sales performance, a diversity index, and

team satisfaction, to score workers on their unionization risk. Google, in an apparent attempt to weed out potential employee organizing, allegedly automatically tips off management when any internal meeting is scheduled with over 100 employees.

■ Anonymous By Design

In the wake of privacy concerns, some developers are building products that recognize and quantify people without revealing individual identities. Anonymizing data after the fact requires exceptional data governance, which is difficult for some companies to achieve but increasingly important in light of GDPR. Piwik Pro is bringing anonymous data collection to the world of marketing and analytics. The practice is not new in fields such as with anonymized health data. Another startup, Density, anonymously quantifies how individuals use space so that companies can create better workplace experiences. Recently,

the startup announced that it raised \$125 million in financing, establishing its valuation at \$1.05 billion.

■ Scoring Companies

China's Corporate Social Credit System (CSCS) is intended to be a standardized reputation-based system to create what the Communist Party of China calls a "fair, transparent, and predictable" business environment. This system applies to both local and foreign entities doing business in China. To regulate corporate behavior, the CSCS will rely on data-gathering efforts that extend to businesses nationwide. Under this system, Chinese companies and trade associations will be required to provide data about foreign partners and enforce blacklists against targeted companies. Threats that both domestic and foreign businesses face from the effort include being subjected to arbitrary rule enforcement or new regulations regarding IP or tech transfer.

Business of Scoring



Voyager Labs alleges that it can determine the public safety risk of an individual by assessing their online profile and personality.

■ Surveillance Scoring-as-a-Service (SSaaS)

The tech giants are building comprehensive systems intended to optimize our daily lives, and those scoring systems have appeal beyond their original use cases. For example, Amazon applied for a U.S. patent for an unmanned aerial vehicle that can perform surveillance from the air and generate images that could be used by others. Surveillance scoring-as-a-service (SSaaS) would be a monetized byproduct of Amazon's drone delivery service, and it would fit into its broader constellation of surveillance scoring technologies. Voyager Labs has proposed to law enforcement that its products can evaluate an individual's ideological beliefs and identify the strength and level of passion of those beliefs. By assessing an individual's social media posts, online friends,

and even indirect online connections, Voyager suggests it can determine the public safety risk of a specific individual. Flock Safety, which just closed a \$150 million Series D round, attempts to fight crime with license plate recognition systems. By using machine learning, the company claims that it can serve investigative leads to law enforcement.

Algorithmic Bias



A 2021 study by The Markup found that Google allowed advertisers to exclude nonbinary people from seeing certain job ads.

■ Verification System Asymmetry

Unlike the three major credit agencies (Equifax, Experian, and TransUnion), which produce scores that typically fall within roughly the same range, the systems that generate scores in the datascape each use different inputs and methodologies to arrive at their answers. Unlike finance, this new consumer scoring has no standardization, the algorithms are automated, and companies cloak methodologies under the premise of proprietary algorithms.

■ Scoring Vulnerable Populations

AI-powered recognition tools have well-documented blind spots. They often return incorrect results for people of color and for trans, queer, and nonbinary individuals. Gender-identifying tools are becoming more widespread. These applications can be found in digital billboards that change depending on who's passing by, and in the verification system for a “girls only” social app

called Giggle. An Equal Pay Day marketing campaign in Berlin used facial scans to attempt to identify women. To counteract these initiatives that have flown under the radar, an ad campaign by Access Now is pushing to have such applications banned in the EU. Os Keyes, a researcher based at the University of Washington, has highlighted how such applications are fundamentally flawed, reducing gender to simplistic binaries. The results are harmful to trans and nonbinary individuals who are not bound by such narrow categorization. Concern arises as law enforcement, immigration officials, banks, universities, and even religious institutions continue to turn to scoring systems.

■ Bias in Scoring Systems

Computers can make decisions faster than humans, but at what potential cost? It is no secret that many of our machine learning models—and the data they use to recognize others—are encoded with

bias. That's because the people who built the models are themselves subject to unconscious bias, as well as more explicit homogeneous learning and working environments. Recently, an investigation by The Markup discovered that lenders are 40%–80% more likely to deny loans to applicants of color than to white applicants. In specific metro locations, the divide is greater than 250%. Despite agreement that it has a bias problem, the tech industry still has no plan for how to address it. Researchers at Yale University are trying to tackle the problem through what they call a “train and mask” technique, in which algorithms are trained with data including sensitive features. After the algorithms are run with this data, the sensitive features are then masked to eliminate these factors in the decision-making process. Without provisions to combat biases in scoring systems, the algorithmic bias problem will likely get worse, especially as more law enforcement agencies and the justice system adopt recognition technologies.

“
**Surveillance capitalism unilaterally claims
human experience as free raw material for
translation into behavioral data.**

— Shoshana Zuboff, writing in *The Age of Surveillance Capitalism*

”

Scoring Standards and Regulation

Select all squares with
traffic lights
If there are none, click skip



reCAPTCHA is a scoring system developed by Google designed to thwart spam and bots.

■ Conflicting Norms, Standards, and Regulations in Scoring

There is no single set of standards nor a unified code of norms for scoring in the United States. The result is a piecemeal approach to regulating scoring and scoring agencies. What we do have are federal sector-specific data protection laws. However, these have precedent from several decades ago and mostly do not account for the changing pace of technology. While many states are more lax when it comes to scoring and data collection, California is considering enacting the Automated Decision Systems Accountability Act to require businesses to test any automated decision systems for bias before deployment. Other states have made moves to implement legislation to regulate automated decision-making, including Massachusetts, Washington, and Illinois. In coming years, the piecemeal approach to algorithmic scoring and data governance

will challenge audience insights, risk and compliance, and distribution for every business.

■ Intentionally Opaque Methodologies

New tools track our online movements and behaviors more covertly than in the past, with the justification that this provides a more seamless user experience. For example, CAPTCHAs (“completely automated public Turing tests to tell computers and humans apart”) have traditionally worked by requesting that users complete a task that’s easy for humans but difficult for computers. When Google acquired reCAPTCHA in 2009, the application functioned in this way. However, more recent versions of the technology work beneath the surface. Rather than asking consumers to click a box saying, “I’m not a robot,” or having them identify partial objects in pictures, the latest version invisibly

tracks how someone navigates a website and assigns a risk score based on that behavior. Rather than relying on direct input from users, this system looks for other details, such as whether someone already has a Google cookie in their browser and whether they are logged in to a Google account. While this process is less annoying, it is more invasive, requiring users to concede extra behavioral and personal data.

China Focus



China's Corporate Social Credit System is an ambitious, nationwide data-gathering effort intended to regulate corporate behavior.

■ Scoring in China

China's Social Credit System, first announced in 2014, is a vast ranking system that has begun to be rolled out. Its promise: to make good on the government's stance that "keeping trust is glorious and breaking trust is disgraceful." While China plans on making the system mandatory for everyone, it currently has not been deployed nationwide. This moral ranking system will eventually monitor the behavior of China's entire population and rank citizens based on their social credit scores. While the algorithmic determination behind the system remains secret, actions that can negatively affect a person's score include bad driving, smoking in undesignated areas, purchasing or playing too many video games, spreading news online that is deemed fake, wasting money, and posting on social media. Punishments for such violations can include travel bans, slowed internet service, bans from higher education,

and restrictions on business class and luxury options. As China continues to roll out its social credit system, in November 2021, it signed a United Nations pledge to prevent AI from wreaking havoc on societies or being used in scoring systems. It will be interesting to see if China acts on this pledge.

■ Scoring Uyghurs

In late 2019, a leak of highly classified government documents revealed an operations manual for detention camps in the far western region of Xinjiang, where scoring is used for predictive policing. It is in this region where China's Muslim Uyghur community lives. The International Consortium of Investigative Journalists published a detailed report showing the scope and ambition of Beijing's scoring system, which assigns points and punishments to inmates in the camps. China argues its "re-education camps" and scoring systems were built to combat terrorism

and radical religious extremism. Further technology has been developed by Chinese companies for the purpose of monitoring and scoring Uyghurs, and now a system using AI and facial recognition can detect their emotions. A creator of this technology anonymously claimed that the software is intended for "prejudgment without any credible evidence."

Cover Story • Near-future optimistic scenario

PRIVÉE MYSTIQUE

Hide in plain sight while still getting noticed.

Smooths wrinkles

Reduces eye puffiness

Instantly blocks surveillance cameras

Our patent-pending beauty technology reduces signs of aging while thwarting facial recognition systems.

Special pigments confuse algorithms.

Flawless coverage to feel your best.

Flawed data to confuse AI.





00

01

02

03

04

05

06

07

08

09

10

11

12

13

Recognition, Scoring & Privacy

Privacy

11TH YEAR ON THE LIST

Privacy



Colorado became only the third U.S. state to enact data privacy legislation.

KEY INSIGHT

Data collection has accelerated with the proliferation of new devices and interfaces. Data privacy regulation, however, has struggled to keep up. Our modern economy relies on exposing more of an individual's personal identity and behaviors in exchange for access, but proposed regulation is on the rise.

EXAMPLES

COVID-19 exposed untold volumes of personal information to the internet ecosystem, and the amount of data exposed may continue to grow with global recovery efforts, which may require border entry surveys documenting people's health details and vaccine passports. The pandemic halted many efforts to enact privacy bills, but those efforts are being revived. U.S. Sen. Kirsten Gillibrand (D-N.Y.) is reintroducing the Data Protection Act, which would create a new data protection agency. Internationally, we are seeing increased privacy initiatives across the European Union, India, and China that focus heavily on restricting movement and the storage of personal data outside of national borders. We are entering a new age of data nationalism.

DISRUPTIVE IMPACT

In the past year, Virginia and Colorado issued state data privacy laws, joining California. These laws may move the United States closer to federal regulation—or at least act as a proxy for federal law—as companies adapt data policies to comply. The Federal Trade Commission, under its newly appointed chair, Lina Khan, is expected to exert its authority to deter data protection violations.

Data privacy regulation is impacting the global economy and foreign investment. China's laws, for instance, threaten to block listings of Chinese companies on foreign stock exchanges based on security reviews of data collection and storage practices. We will likely see the increased influence of global politics in data privacy regulation.

EMERGING PLAYERS

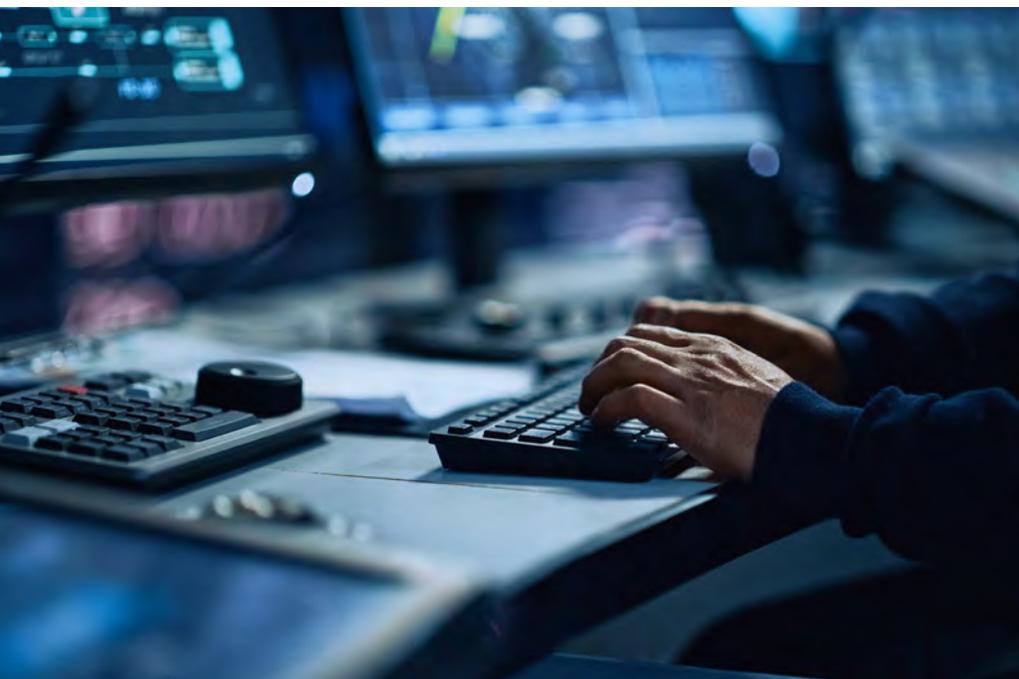
- Dr. Nicol Turner Lee, director of the Brookings Institution's Center for Technology Innovation
- Electronic Frontier Foundation
- Jennifer Granick, surveillance and cybersecurity counsel at the American Civil Liberties Union's Speech, Privacy, and Technology Project
- Dr. Arvind Narayanan, associate professor of computer science at Princeton University, and affiliate, Center for Information Technology Policy
- Future of Privacy Forum
- Center for Democracy and Technology
- National Institute of Standards and Technology

“
**Privacy with medical information is a fallacy.
If everyone’s information is out there, it’s
part of the collective.**

— J. Craig Venter, geneticist, biochemist and biotechnology pioneer

”

Workplaces and Schools



Worker surveillance is expanding beyond cameras into “tattleware” that tracks employee activity (or lack of activity) on laptops.

■ Worker Surveillance

The rise of remote work during the pandemic accelerated the surveillance of workers. Interest in employee surveillance has risen 58% since the onset of the pandemic and will likely continue to grow as remote and hybrid work conditions continue. The U.S. Fourth Amendment, which would prevent most uses of this same technology by law enforcement, doesn't apply to private companies. Teleperformance, a company that manages outsourced call center work for many Fortune 50 companies, uses cameras and AI to monitor its teams. It flags employees as idle when it detects they haven't used the keyboard or mouse within a specified time frame. Live Eye Surveillance offers a monthly subscription service that will remotely monitor live video feeds of employees for employers such as 7-Eleven, Dairy Queen, and Holiday Inn. Sneek is another example of “tattleware” that captures

live photos of employees via webcams and displays them on a digital wall viewable by everyone in the company. Click on a photo and it instantly pulls that person into a video call with you.

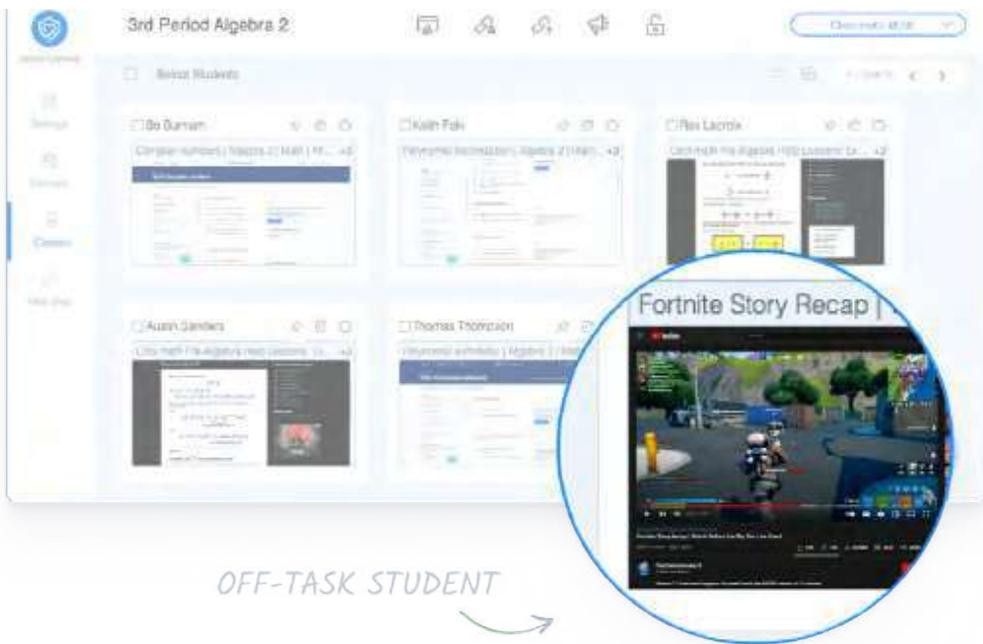
The most well-known user of worker surveillance might be Amazon, which has installed AI-enabled cameras in delivery trucks to track behavior and reduce driver pay if it perceives unsafe conditions such as distracted driving, speeding, or hard braking. In its warehouses, the company monitors worker productivity by measuring Time Off Task, which is any time when a worker isn't actively processing products. South Korean e-commerce giant Coupang, which has pledged to become the “Amazon of Korea,” uses similar surveillance tactics. AB 701, a law passed by California in September 2021, may mark the start of government intervention in AI-enabled quotas that inhibit rest periods and bathroom breaks.

The industry has also continued to evolve as it offers more AI-based analysis of workers. Amazon is exploring using keystroke-logging software that tracks user behavior over time to detect if the same person is controlling the worker's account. Aware's Spotlight software detects behavioral changes like mood, tone, and attitude across conversations on employees' devices. Teramind offers software that will disable private conversations if it detects “inappropriate” keywords. With the top three tools in the industry accounting for over 60% of global demand, expect to see more AI-based surveillance that leverages the growing pool of data collected by these companies.

■ Privacy and Unionizing at Big Tech

Amazon employees started an anti-surveillance petition in 2020 with a singular message: “Stop spying on us.” Amazon

Workplaces and Schools



Surveillance software firms like Securly were contracted by school districts to monitor students' online activity.

has developed or licensed workplace surveillance technology that tracks employees across the organization, with tools including algorithmic time tracking and “tattleware” installed on employee laptops. Many employees fear speaking out, however. Even Apple, which positions itself as an industry leader in privacy, sent out a company-wide memo warning that employees who spoke out about working conditions would be found. Hundreds of Google employees similarly complained of surveillance as they attempted to organize. The new union, formed within the company’s ranks and called the Alphabet Workers Union, was kept secret until the group elected its leadership and forged an alliance with the Communications Workers of America.

■ School Surveillance

During the pandemic, many students were issued laptops and other devices

by schools to facilitate remote learning. They weren’t told, however, that these devices would open a portal into their homes that could be monitored by schools at all times of the day. In the U.S. and many other countries, schools can legally monitor students, often without disclosing what is being tracked. Gaggle is a company that monitors school-issued accounts and uses AI to track online behavior of students across services like email, Google Hangouts, and chat tools. In 2020, the Minneapolis school district signed a contract with the company to monitor its students through 2023. A school district in California contracted with Securly to monitor students in real time, looking for prohibited behaviors such as having too many browser tabs open. The software enables teachers to close tabs for any students they believe are “off task.” Philadelphia and Chicago schools deployed GoGuardian software on district-issued

Chromebooks. A vulnerability in the software allowed teachers to start virtual sessions that enabled webcams on those Chromebooks without notification or consent by the student. Outside of the U.S., schools in China deploy technology to monitor attentiveness in students. An algorithm called 4 Little Trees is used in Hong Kong to detect students’ emotions as they learn—by monitoring their facial expressions with webcams. If the system detects a lack of focus, it nudges the student to pay attention.

Surveillance Technology



Technology advances in cameras and facial recognition are creating drones that can identify targets and track them around city obstacles.

■ Non-Line-of-Sight Tracking

During the pandemic, researchers at Penn State used fiber optics to surveil the campus from below the surface. Using distributed acoustic sensing technology, the scientists converted fiber optics into seismic sensor arrays that could detect subtle signals such as people walking. Urban pedestrian and vehicular traffic created vibrations that disturbed the light pulses carried in the fiber optic cables, imperfections that could be detected and linked to a source. The technique demonstrated by the researchers was capable of tracking data approximately every 6 feet, providing reasonable resolution of movement.

■ Drone Surveillance

Drones are used in a variety of settings for surveillance. Advanced camera technology can capture video in 4K, while machine learning software

identifies people, locks onto targets and follows them, and even guesses what a target will do next. Skydio drones are reportedly able to navigate tight spaces in buildings or dodge outdoor obstacles such as trees and light posts. Some drones from Shenzhen-based DJI include sensors that can measure an individual's body temperature and heart rate, in daylight or infrared. Drones are increasingly used by local law enforcement at events such as protests, where they can identify and track participants and potentially intercept calls and texts.

■ Depth of Field Recognition

3D cameras with good depth of field—originally intended for high-quality content creation—are being repurposed as surveillance systems. 3D cameras combined with LiDAR generate wireframes that enable facial recognition, even when a face is obscured by a mask

or glasses. This technology also improves object recognition by using deep learning to understand how certain features differ in various environments and change over time.

Personal and Biological Privacy



California enacted legislation that requires direct-to-consumer genetic testing companies like 23andMe to obtain explicit consent for use of a person's genetic information.

■ Personal Electronic Keys

Electronic entry to homes and vehicles has become standard. It's an embedded feature in Apple's iOS 15, which includes the ability to require additional authentication, much like Apple Pay does. The technology has been evolving by including more contextual factors into authentication. Plurilock uses behavioral signatures based on input patterns and physical location. The U.S. Army tested using smartphone motion sensors to identify and authenticate users by their walk. Researchers at Beijing Jiaotong University have proposed using a person's posture as a contextual signature.

■ Leaky Health Apps

Consumers are frequently turning to apps to get help with mental health, monitor chronic disease, and track health details, but they frequently don't realize that their personal health information is being shared outside of the apps. In a study conducted by

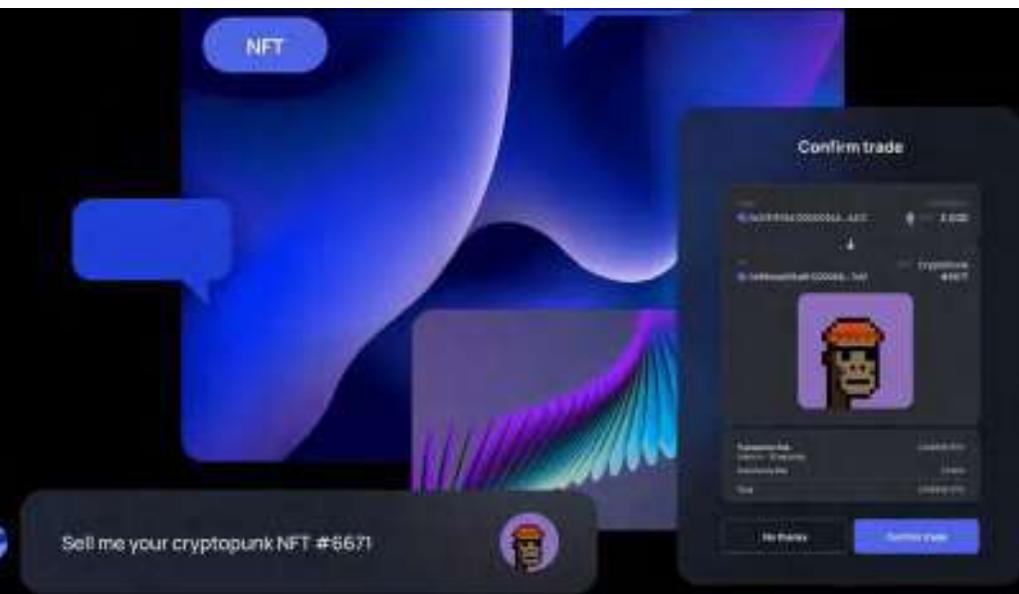
ExpressVPN's Digital Security Lab, the Opioid Policy Institute, and the Defensive Lab Agency, researchers found that opioid-addiction recovery apps shared access to data including unique identifiers with third parties such as Facebook and Google. In many cases, privacy policies outlined this use as personalized advertising. In the U.K., a study of over 20,000 Android health apps found similar results, with most apps sharing personal data. In the U.S., the Federal Trade Commission warned developers that apps and devices that collected personal health data were required to notify users of data breaches or if data was shared with third parties without consent.

■ Biological Privacy

California recently enacted the Genetic Information Privacy Act, which introduces data restrictions on direct-to-consumer (D2C) genetic testing companies such as 23andMe and Ancestry. The law requires explicit consent for use of a per-

son's DNA in research or in third-party agreements, and bans deceptive practices to trick or coerce people into granting consent. It also has a provision enabling customers to request that their data be deleted and any samples be destroyed. California was only the latest state to pass such a law. Utah and Arizona both passed similar genetic data protection laws in 2021. Maryland and Montana also passed forensic genealogy laws that require search warrants to view data in D2C DNA databases for a criminal investigation. Maryland restricts its law enforcement agents further by limiting use of these databases to cases of murder, rape, and other violent crimes that present a serious societal threat. Businesses are also emerging with privacy solutions to help companies comply with the various data privacy laws in place across the globe. TripleBlind developed an encryption method that enables companies to share data without having to decrypt or transfer it.

Networks



Secretum is a decentralized application built on the Solana Blockchain that enables fully encrypted messaging.

■ Encrypted Messaging Networks

While many messaging apps such as WhatsApp, Signal, and Telegram offer end-to-end encryption, that doesn't guarantee privacy. Hackers were able to break into Telegram accounts of Brazilian officials, and in 2020 the company faced two data breaches, one of which exposed personal details of more than 500 million users. Two newer messaging apps take a more secure approach to user data. Secretum is a decentralized, encrypted app built on the Ethereum and Solana blockchains. Because the app is built on the blockchain, identity is based on a crypto wallet address, so names, phone numbers, and other real-life identifiers aren't required. Session also runs on blockchain. Early user targets included journalists and activists. With the rise in hacks and revelations about the expanding reach of government surveillance programs, we expect more people to look to encrypted messaging as an option for preserving their privacy.

■ Mobile Tracking

5G was supposed to make our cellular systems safer, but many carriers rolled out networks that relied on existing 4G infrastructure as a stopgap measure until a stand-alone 5G core could be built. This means that some "5G" connections retain the same privacy weaknesses as before—mainly vulnerability to tracking and eavesdropping. One major flaw is susceptibility to stingrays—or international mobile subscriber identity (IMSI) catchers—that mimic cell towers. If a device is tricked into connecting, the stingray can use the IMSI to track that device and listen to phone calls. Currently, consumers don't have an option to block vulnerable non-stand-alone mode connections, ensuring that they remain susceptible to digital surveillance nets.

In some Latin American countries such as El Salvador and Honduras, governments use software from cybersecu-

rity companies to bypass smartphone encryption and privacy protections. Authorities in Guatemala used Magnet AXIOM software to recover deleted information on mobile phones. In Brazil, however, protections against self-incrimination were upheld when the Superior Court of Justice ruled that defendants couldn't be forced to turn over device passwords. Despite this, the technology will likely continue to advance more quickly than our legal protections.

Of course, stingrays and decryption software are not the only ways phones expose personal data. Apps collect location and usage details that are sold to third-party data brokers and made available on marketplaces such as Amazon's AWS Data Exchange and the Oracle Data Marketplace. Customers for this data are expanding beyond advertisers and include political campaigns, government agencies, and commercial real estate firms.

Networks



The 2020 US Census used differential privacy to maintain personal confidentiality in public releases of the census data.

Apple's App Tracking Transparency function launched in April 2021 and allows users to block a company's app from tracking their activity across other apps and websites. When Apple released the feature in iOS 14.5, the impact was felt across the internet, but especially on social media platforms that rely on tracking to support their ad businesses. The Financial Times estimated that the move cost Snap, Facebook, Twitter, and YouTube \$9.85 billion in revenue in the second half of 2021. And it didn't stop there.

Few people realize how much personal information they give away simply by opening an email. With iOS 15, Apple introduced privacy features such as the ability to block email-tracking pixels that senders use to collect user data and the ability to privatize online activity with anonymous IP addresses and encrypted internet traffic. The Hide My Email feature uses random email addresses

that forward to a user's main email when interacting with businesses so that people never have to expose their personal email address. While there are still trackers everywhere, new tools may start to level the playing field.

■ Differential Privacy

Differential privacy is a statistical method that intentionally introduces errors in data to obscure individual identities of participants in the dataset. Also known as "epsilon indistinguishability," it was developed as a mathematical concept in 2006 by Cynthia Dwork, Frank McSherry, Kobbi Nissim, and Adam Smith. Apple's privacy-minded machine learning relies on differential privacy: It allows the company to extract data from iPhones and anonymize it while still drawing useful insights. Google has a differential privacy library on GitHub. Depending on applications and datasets, differential privacy can be hard to maintain, and there is

little regulatory guidance. Differential privacy was used by the Census Bureau in the 2020 census, sparking 16 states to sue on the basis that the approach violated the Bureau's mandate to accurately report population data. The case may force the U.S. government to establish guidance around the use of this method in reporting government data. The Bureau may turn to releasing the American Community Survey as a synthetic dataset—it would mimic the original data without exposing the underlying data.

■ Quantum Encryption

The quantum era is expected to bring breakthroughs in molecular discovery, artificial intelligence, and prediction models for financial markets and weather, but these same capabilities are what will enable it to break our current encryption mechanisms in seconds. The National Institute of Standards and Technology is just one organization that has

been working to develop quantum-resistant algorithms in collaboration with teams across industry, academia, and other countries to ensure people's private details remain private. NIST expects to release a draft of its post-quantum cryptography standard for public comment in 2022 or 2023 with a finalized standard available by 2024.

Law Enforcement and Regulation



Federal agencies like the US Customs and Border Protection have been linked to searches using software from controversial facial recognition company Clearview AI.

■ Public Entities Buying and Selling Personal Data

Many U.S. state agencies sell personal data. Colorado, for instance, sells DMV (Department of Motor Vehicles) data to third-party data vendors that are not required to report details of subsequent sales. In November 2020, data broker LexisNexis settled a class-action lawsuit alleging inappropriate sale of this data. Privacy-minded citizens have no recourse under the Driver's Privacy Protection Act of 1994, which legalizes this practice and prevents anyone from opting out. But states have been coming under greater scrutiny for selling data, and in 2021 Texas lawmakers passed a bill that ended the practice.

U.S. government agencies are also buying data and may be violating Fourth Amendment protections as a result. One company at the center of this controversy is Clearview AI; the New York-based facial recognition company has been

courting federal agencies and law enforcement departments by marketing a database of over 3 billion images scraped from social media sites including Facebook and LinkedIn. Clearview CEO Hoan Ton-That claims the program was used to identify people who participated in the Jan. 6, 2021, events at the U.S. Capitol, but agencies including the FBI, U.S. Customs and Border Protection (CBP), and all branches of the military have been linked to searches using the software.

Federal agencies have also been found to buy mobile phone location data. According to The Wall Street Journal and Motherboard, the IRS, Department of Homeland Security, and branches of the military purchased this data from brokers, bypassing official channels. One of those data brokers is Venntel. CBP has spent hundreds of thousands of dollars to access the company's location data. X-Mode is another company that sells location data captured from apps to government contractors.

There is little regulation around the use of commercialized data by government agencies and law enforcement. Purchasing this data lets agencies bypass justification of cause for a warrant, subpoena, or court order. Instead of compelling providers like AT&T or Verizon to provide location data, agencies can rely on our frequent use of smartphone apps that collect this data for them. In other words, when you check the latest weather or scroll social media, your location may be scooped up by the U.S. government.

■ Crowdsleuthing

Crowdsleuthing is the practice of internet users banding together to solve mysteries and crimes. A digitized evolution of anonymous tip lines and TV series like "Unsolved Mysteries," crowdsleuthing heavily relies on social platforms both as a source of clues and as a channel for cultivating volunteers. One impactful collective, Distributed Denial of Secrets, was

Law Enforcement and Regulation



Distributed Denial of Secrets scraped data from the right-wing platform Parler to document posts during the January 6 attack on the US Capitol.

Credit: Distributed Denial of Secrets

linked to the 2020 release of law enforcement data known as BlueLeaks as well as to an extensive trove of data scraped from right-wing platform Parler during the Jan. 6, 2021, attack on the U.S. Capitol. A more recent example of crowd-sleuthing is the group of “digilantes” who rallied around the case of Gabby Petito, a 22-year old woman who went missing during a road trip with her fiancé. The case sparked updates and theories posted across TikTok, Instagram, and Twitter. Those posts may have led investigators to discover Ms. Petito’s remains. But crowd-sleuthing efforts don’t always end well. The same motivations that lead to solving cases also empower amateurs posing as experts to spread conspiracy theories or misinformation.

■ Preventing Digital Self-Incrimination

Because our connected devices are continuously monitoring us, they are perfect witnesses to testify to our activities and

locations. Judges are deciding cases now that determine how this data will be used and whether sharing data to a company-owned cloud or other third party undermines our expectation of privacy. Geofence warrants are being used to compel telecom providers and tech companies to identify anyone in a location within a specified time window—typically by tracking mobile phone connections to towers and Wi-Fi routers—and provide personal data that can then be used by investigators to identify suspects. Before you’ve even been suspected of doing something wrong, your data can become part of the investigation.

But data from wearables and smart-phones isn’t the only tattletale. Keyword search warrants are being used by law enforcement to identify anyone who searched for specific words, phrases, or information about a victim. In one investigation, Google, Microsoft, and Yahoo were ordered to turn over IP addresses and account information for individuals

who searched for certain addresses and terms like “pipe bomb.” When terms are generic and combined with broad time windows, the probability of including innocent people grows. The practice raises concerns about how it may violate First Amendment rights.

Photos are another way we may be digitally incriminating ourselves. In the fall of 2021, Apple announced a Child Sexual Abuse Material (CSAM) function that would analyze images on users’ devices to determine if any of the photos matched known CSAM images. The feature was postponed after significant public backlash that the on-device scanning capabilities would be expanded to serve other government uses such as spying on political dissidents.

■ Privacy Regulation

More U.S. states are taking steps to protect consumer privacy rather than wait for federal legislation. Colorado and

Law Enforcement and Regulation



EU regulations will prevent transfer of data outside of member states if privacy laws in a processing country do not meet their criteria.

Virginia joined California in enacting comprehensive consumer data privacy laws. The new laws take effect in 2023. Florida failed to pass its Florida Privacy Protection Act in April 2021. It was slated to become the strictest law in the country, granting consumers the right to sue businesses directly for privacy violations. In all, 38 states introduced over 160 consumer privacy-related bills last year. Privacy of genetic data also came into focus, with six states passing bills to protect consumer genetic information. Although 24 states introduced bills to regulate biometrics, none passed.

In April 2021, a bill named The Fourth Amendment Is Not For Sale Act was introduced by U.S. Sens. Ron Wyden, Rand Paul, and 18 others. The bill targets legal loopholes that let law enforcement agencies purchase private data from commercial entities in lieu of obtaining a warrant. A separate bill, The Data Protection Act, was reintroduced in 2021. It would establish a data protection agency

charged with conducting investigations and responding to consumer complaints. The agency would also be responsible for developing data privacy standards and outline prohibited practices like reidentifying individuals from de-identified data. In addition to legislation, the U.S. may act through the Federal Trade Commission under its chair, Lina Khan. While antitrust is expected to be Khan's highest priority, the FTC could act under its statutory rulemaking authority on data privacy issues that are likely part of the agenda.

Facial recognition company Clearview AI has been ordered by Australian regulators to destroy all images and facial templates belonging to Australian residents. The company claims that, because the images were collected from publicly available sources, no breach of privacy occurred. The case will test the extent to which privacy cases that target companies with global operations can enact change.

Last June, the European Commission issued new standard contractual clauses for the transfer of personal data outside of EU member states. While some countries including Canada have received decisions that their national privacy laws are adequate to ensure secure transfers, the U.S. has struggled to establish a framework for continued data transfers. Given U.S. surveillance laws like the U.S. Cloud Act and the Foreign Intelligence Surveillance Act, EU regulators found that its citizens would not have the same privacy protections afforded to them under EU law while using U.S.-based services. Global cloud providers including Google, Amazon, and Microsoft will be significantly challenged to find a resolution quickly; some American companies may choose to store and process data locally to avoid risk of sanctions.

China has also been acting under the name of data privacy. Following ride-hailing app Didi Chuxing's IPO, the

Cyberspace Administration of China banned the app from all Chinese app stores. China is also taking a closer look at financial structures such as variable interest entities (VIEs) that create loopholes around laws restricting foreign investment. Going forward, companies seeking to go public as VIEs will need regulatory approval.

Your Body, Your Home: An FAQ

Why did my smart home's conservatorship system activate?

If your smart home and your wearable devices detected erratic behavior—which might include memory loss, significant emotional distress, or a noticeable physical impairment—your AI conservator activated to protect you from potential harm. Some devices may include biomarker tracking. In that case, your biomarkers can reveal cognitive decline long before you, your friends or relatives might sense that anything is wrong.

A temporary AI conservatorship is established when individuals such as yourself are unable to make sound decisions on their own.

What does the AI conservator control?

The AI conservator, once activated, acts as an intermediary between you and all of the smart devices and smart home ecosystem registered to your account(s).

When you opted in to your device ecosystem's expanded offerings, you asked your technology platform provider to protect you in your connected home.

The AI conservator will now make decisions on your behalf. You will temporarily be banned from making large purchases. You may find that your stove or oven will automatically turn on and off—this is normal.

Why won't my garage door open?

If you lease or own a vehicle and it is parked in your garage, your

AI conservator may deem you ineligible to drive. This may be temporary.

Can my adult children or a third party negotiate with the AI conservator?

Yes. If you designated an adult to act on your behalf before the AI conservator activated, and if that adult is deemed sound by the AI conservator, that person can negotiate on your behalf.

Can I petition to have the AI conservator deactivated?

Yes, however any request made requires one week's worth of data for analysis. During that time, you may come and go freely from your smart home, however your wearable devices must remain on your body and powered on at all times.



Safeguarding Privacy



Nonprofit ProPublica raised controversy when it published leaked tax payer records of wealthy Americans.

■ Eavesdropping Rights

Our devices know a lot about us. From voice assistants to wearables, they regularly send data to third parties as well as device manufacturers. Smart meters provide detailed data about activities while smart lock data tracks movement in and out of the home. In the U.S., the AI Bill of Rights proposed by the Biden administration may change the nature of that data exchange. It outlines a freedom from “pervasive or discriminatory surveillance and monitoring in your home, community, and workplace” that may start to constrain use of personal data or prevent that data from being collected by external servers. Alternatively, users may seek out voice assistants from companies that offer a greater level of privacy. Sensory’s voice-enabled Farberware microwave doesn’t even require an internet connection, so your data stays safely with you. Even incumbents have been forced to change: Apple announced

that requests made to Siri remain on the device and will no longer be sent to servers for analysis or storage. The move is likely in response to lawsuits being heard now alleging privacy violations by smart devices.

■ Safeguarding and Verifying Leaked Data

Many social movements worldwide encourage the leaking of sensitive information to counter corruption and malfeasance, but there is less agreement about what data should be published and who should make those choices. In September 2021, email and chat data reportedly from the far-right paramilitary group the Oath Keepers was released by journalist collective DDoSecrets, exposing member and donor details and communications. In October, the International Consortium of Investigative Journalists (ICIJ), a network of 280 investigative reporters from over 100 countries, announced its latest

investigation, the Pandora Papers, which exposed the shadow financial system sheltering the global elite. The ICIJ is the same organization that led the Luanda Leaks and Panama Papers investigations. In June 2021, nonprofit ProPublica published The Secret IRS Files, leaked tax records of wealthy American taxpayers that sparked renewed calls for tax reform. With rising polarization, reporting on perceived injustice using internal data leaks are here to stay. So are politically motivated hacks.

China Focus



Chinese surveillance systems are expanding beyond national borders into other countries.

■ China's Panopticon

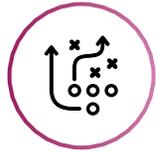
China collects massive amounts of data—on its own citizens and others around the world. The Chinese Communist Party (CCP) places a priority on data for surveillance, political stability, and economic growth. The CCP collects data through government surveillance systems and commercial social networks. Its reach is staggering; the government scrapes data from smart city infrastructure, school records, apps, and payment systems. In the past, the country's population of over 1.4 billion people offered researchers and startups access to a continuous pipeline of data without the kind of privacy and security restrictions that are more common in other countries. But that is beginning to change.

China's Personal Information Protection Law (PIPL), which took effect on November 1, 2021, is just the latest in a national campaign to reassert government control over user data. The law targets private

companies (government-controlled data will not be impacted) and even extends beyond Chinese borders in some cases. The law is in part a response to increased calls for consumer privacy that have risen as the collection and use of personal data for commercial purposes have expanded. Companies outside of China will need to comply when processing data generated by Chinese individuals or collected in the process of delivering products and services within China. Any Chinese data sent overseas will require explicit permission. Penalties for violating the law are steep—up to 5% of the company's annual revenue the prior year—and are designed to discourage any attempts to bypass compliance. PIPL follows closely the passing of the Data Security Law in June 2021; both indicate that the CCP views preventing personal data from leaking outside of its national borders as a critical aspect of national security.

As for consumer privacy rights, new guidelines from China's Supreme People's Court went into effect on August 1, 2021, prohibiting hotels, retailers and other businesses from using facial recognition without consent. Companies that already have this data will be required to delete face scans upon consumer request. These laws, however, only protect Chinese citizens from commercial surveillance within Chinese national borders. In other countries, Chinese companies such as Huawei, ZTE, and Alibaba are installing surveillance systems as part of smart city initiatives. While these systems may offer cost-efficient surveillance, there is no guarantee that sensitive data won't be shared with the Chinese government or that the systems won't support a rise in authoritarianism.

How these trends impact your company



STRATEGY

Recognition, scoring and privacy are strategic challenges as well as opportunities for growth. Algorithmic scoring systems automate factors of strategic importance to companies—consumer intent, financial risk, workplace satisfaction—but they should be used as part of a clear set of plans and actions. Approach scoring with unconventional or contrarian thinking: What will be scored, and why? How would scoring lead to downstream risk for our business? How does scoring fit into our longer-term growth ambitions? Chief strategy officers should take an active role in these conversations.



INNOVATION

In what ways could algorithmic scoring itself be improved? Companies that engage in scoring have ample opportunity to disrupt the current model and make needed improvements to address bias, how vulnerable communities are scored, and how the vast dimensions of people are reflected in outcomes. Innovation teams can play an important role by working together with product, risk, consumer insights, UX, and e-commerce teams on their expectations and road maps.



R & D

R&D teams working on algorithms and scoring need to have a good degree of autonomy to design, build, and test new ideas and to experiment with models—but given the sensitive nature of scoring, they should coordinate their activities with strategy, innovation, and risk teams. New research should prioritize transparency. Show other teams what work is in progress, and invite discussion about ethics and accountability. This will build trust within the company and will ensure an easier go-to-market strategy down the road, whether the intended customers are other teams inside the organization or external people and customers.



GROWTH

Scoring presents tremendous opportunities to help businesses understand their customers better. But the challenge is data: high-quality data, ethically sourced, can be difficult to get and it still must be cleaned, refined and accessible by others within the organization. Companies should prioritize good data collection and governance practice in 2022.

Key Questions

We recommend using this report to support your strategic foresight activity in the coming year. Every executive team should begin by asking these questions:

1

- ▶ With regard to scoring, what is our position on transparency, ethics, and accountability?

- ▶ Do our employees understand this position?

- ▶ Do our customers?

2

- ▶ Do our current data hygiene and data governance policies create vulnerabilities?

- ▶ Some teams may first need to ask: Do we even have a data hygiene or data governance policy?

3

- ▶ If we rely solely on third parties for algorithmic recognition and scoring, what opportunities are we leaving on the table?

- ▶ If we sourced more data, could we develop new insights about our customers?

Selected Sources

<https://www.ncsl.org/research/telecommunications-and-information-technology/2021-consumer-data-privacy-legislation.aspx>

<https://www.brennancenter.org/our-work/analysis-opinion/federal-agencies-are-secretly-buying-consumer-data>

<https://www.biometricupdate.com/202105/plurilock-wins-three-behavioral-biometric-security-contracts-updates-mfa>

<https://www.axios.com/china-data-privacy-law-foreign-businesses-297f3d9c-51a9-4053-91c2-fd27e4f89274.html>

<https://arstechnica.com/gadgets/2021/10/google-fi-is-getting-end-to-end-encrypted-phone-calls/>

<https://www.theinformation.com/articles/how-amazon-is-using-high-tech-cameras-to-rate-driver-safety>

<https://www.vice.com/en/article/dyve->

<https://www.vice.com/en/article/dyve->

<https://news.bloomberglaw.com/bloomberglaw-analysis/analysis-dealing-with-data-new-contract-obligations-are-coming>

<https://www.apple.com/newsroom/2021/06/apple-advances-its-privacy-leadership-with-ios-15-ipados-15-macos-monterey-and-watchos-8/>

<https://www.pymnts.com/health-care/2021/apple-takes-bigger-bite-in-to-healthcare-tracking/>

<https://securityboulevard.com/2021/04/contextual-biometrics-for-improved-application-security/>

<https://www.euractiv.com/section/digital/news/media-sector-fears-eu-ban-on-targeted-advertising/>

<https://www.theguardian.com/us-news/2021/sep/16/geofence-warrants->

[reverse-search-warrants-police-google](https://www.theguardian.com/us-news/2021/sep/16/geofence-warrants-)

<https://www.nbcnews.com/tech/tech-news/big-tech-call-center-workers-face-pressure-accept-home-surveillance-n1276227>

<https://www.forbes.com/sites/thomasbrewster/2021/03/03/drones-with-most-advanced-ai-ever-coming-soon-to-your-local-police-department/>

<https://www.forbes.com/sites/thomasbrewster/2021/10/04/google-keyword-warrants-give-us-government-data-on-search-users/>

<https://www.zdnet.com/article/sensors-new-voice-assistants-do-not-sacrifice-your-privacy-or-send-data-to-the-cloud/>

<https://www.biometricupdate.com/202107/court-rules-apple-possesses-users-biometric-data-privacy-suit-goes-ahead>

<https://www.californiaemploymentlawreport.com/2021/09/>

[california-passes-law-regulating-quotas-in-warehouses-what-employers-need-to-know-about-ab-701/](https://www.californiaemploymentlawreport.com/2021/09/)

<https://arstechnica.com/tech-policy/2021/08/uber-asked-contractor-to-allow-video-surveillance-in-employee-homes-bedrooms/>

https://www.washingtonpost.com/world/facial-recognition-china-tech-data/2021/07/30/404c2e96-f049-11eb-81b2-9b7061a582d8_story.html

<https://www.scmp.com/tech/big-tech/article/3137247/chinas-data-privacy-country-crack-down-spy-cameras-it-tightens>

<https://www.scmp.com/tech/big-tech/article/3140573/chinas-big-tech-face-wake-call-countrys-web-data-protection-laws>

<https://news.bloomberglaw.com/privacy-and-data-security/chinas-privacy-law-adds-to-international-compliance-patchwork>

<https://www.scmp.com/tech/big-tech/article/3146873/new-privacy-law-china-could-reshape-cross-border-data-rules-similar>

<https://www.buzzfeednews.com/article/ryanmac/clearview-ai-international-search-table>

<https://www.consumerreports.org/privacy/connected-devices-share-more-data-than-needed-study-says-a7015033345/>

<https://www.cpomagazine.com/data-privacy/court-hears-arguments-over-differential-privacy-method-used-to-anonymize-census-data/>

<https://www.theguardian.com/commentisfree/2021/oct/11/us-students-digital-surveillance-schools>

<https://www.fiercehealthcare.com/tech/data-privacy-solution-tripleblind-secures-24m-backed-by-general-catalyst-mayo-clinic>

<https://www.fedscoop.com/>

Selected Sources

<https://www.statnews.com/2021/09/15/digital-health-measures-research-wearables/>

<https://www.forbes.com/sites/zakdoffman/2021/10/30/why-apple-iphone-google-android-and-windows-10-users-need-cross-platform-messaging/>

<https://www.eff.org/pages/dronesunmanned-aerial-vehicles>

<https://news.bloomberglaw.com/privacy-and-data-security/eu-board-advises-companies-to-assess-foreign-data-surveillance>

<https://www.computerweekly.com/news/252502011/EU-privacy-chief-investigates-use-of-US-cloud-services>

<https://social.techcrunch.com/2021/10/21/inside-a-european-push-to-outlaw-creepy-ads/>

<https://www.ijdsupra.com/legalnews/florida-businesses-dodge-a-data-privacy-8177107/>

<https://www.ftc.gov/news-events/press-releases/2021/09/ftc-warns-health-apps-connected-device-companies-comply-health>

<https://www.wired.com/story/borrowed-school-laptop-mind-open-tabs/>

<https://www.investing.com/news/cryptocurrency-news/goodbye-telegram-here-comes-secretum-2661718>

<https://www.zdnet.com/article/colorado-becomes-latest-state-to-pass-data-privacy-law/>

<https://www.wired.com/story/california-senate-passes-warehouse-workers-bill-taking-aim-at-amazon/>

<https://www.theguardian.com/technology/2021/jun/07/apple-overhauls-siri-to-address-privacy-concerns-and-improve-performance>

<https://www.theatlantic.com/ideas/archive/2021/10/china-america-surveillance-hikvision/620404/>

<https://www.businessinsider.com/drone-technology-uses-applications>

<https://news.bloomberglaw.com/privacy-and-data-security/is-chinas-new-personal-information-privacy-law-the-new-gdpr>

<https://www.cnbc.com/2021/09/24/apples-ios-changes-hurt-facebooks-ad-business.html>

<https://www.businessinsider.com/amazon-ai-cameras-score-driver-safety-decide-pay-employment-report-2021-8>

<https://www.the74million.org/article/dont-get-gaggled-minneapolis-school-district-spends-big-on-student-surveillance-tool-raising-ire-after-terminat>

<https://www.the74million.org/article/gaggle-spy-tech-minneapolis-students-remote-learning/>

<https://www.ft.com/content/76fdac7c-7076-47a4-bcb0-7e75af0aadab>

<https://www.washingtonpost.com/technology/2021/09/02/apple-siri-law-suit-privacy/>

<https://www.vice.com/en/article/epddy4/lexisnexis-dmv-data-class-action-settlement>

<https://9to5mac.com/2021/08/09/apple-call-center-workers-surveillance/>

https://www.theregister.com/2021/07/02/us_government_cloud/

<https://www.theguardian.com/uk-news/2021/oct/14/amazon-asks-ring-owners-to-respect-privacy-after-court-rules-usage-broke-law>

<https://www.axios.com/fcc-member-targets-chinese-drone-giant-129f1c80-6d32-4791-a954-37c88466542e.html>

<https://www.nist.gov/blogs/taking-measure/post-quantum-encryption-qa-nists-matt-scholl>

Mandalari, Anna Maria, Daniel J. Dubois, Roman Kolcun, Muhammad Talha Paracha, Hamed Haddadi, and David Choffnes. "Blocking Without Breaking: Identification and Mitigation of Non-Essential IoT Traffic." ArXiv:2105.05162 [Cs], May 11, 2021.

<https://www.nist.gov/blogs/taking-measure/post-quantum-encryption-qa-nists-matt-scholl>

<https://www.ft.com/content/4c19e387-ee1a-41d8-8dd2-bc6c302ee58e>

<https://www.businessinsider.com/fast-food-surveillance-company-agot-ai-uses-computer-vision-2021-10>

https://www.theregister.com/2021/07/02/us_government_cloud/

<https://www.theguardian.com/uk-news/2021/oct/14/amazon-asks-ring-owners-to-respect-privacy-after-court-rules-usage-broke-law>

<https://www.axios.com/fcc-member-targets-chinese-drone-giant-129f1c80-6d32-4791-a954-37c88466542e.html>

Selected Sources

<https://www.vox.com/re-code/22038383/dhs-cbp-investigation-cellphone-data-brokers-venntel>

<https://www.vox.com/re-code/2021/6/17/22536907/gillibrand-data-protection-act-privacy>

<https://www.vox.com/re-code/22570076/health-apps-privacy-opioid-addiction-app-report>

<https://www.ft.com/content/c0b03d1d-f72f-48a8-b342-b4a926109452>

<https://www.npr.org/2021/01/11/955513539/how-online-sleuths-identified-rioters-at-the-capitol>

<https://slate.com/technology/2021/08/census-bureau-differential-privacy-lawsuit.html>

<https://duo.com/decipher/newly-proposed-bill-bars-federal-agencies-from-buying-data>

<https://www.wired.com/story/5g-network-stingray-surveillance-non-stand-alone/>

<https://www.wired.com/story/pretty-good-phone-privacy-imsi-wireless-carriers/>

<https://www.bbc.com/news/uk-england-somerset-57568711>

<https://cointelegraph.com/news/no-outages-no-data-leaks-the-new-whatsapp-killer-built-on-the-blockchain-creates-privacy-focused-encrypted-messenger>

<https://minnesota.cbslocal.com/2021/10/31/people-homes-vanish-due-to-2020-census-new-privacy-method/>

<https://www.washingtonpost.com/outlook/2021/04/26/constitution-digital-privacy-loop-holes-purchases/>

<https://www.brookings.edu/tech-stream/how-china-harnesses-data-fusion-to-make-sense-of-surveillance-data/>

<https://restofworld.org/2021/latin-america-phone-security/>

<https://www.getrevue.co/profile/themarkup/issues/president-biden-s-executive-order-on-big-tech-687031>

<https://www.expressvpn.com/digital-security-lab/opioid-telehealth-research>

<https://www.natlawreview.com/article/proposal-to-create-data-protection-agency-reintroduced-senate>

<https://www.propublica.org/article/the-inside-story-of-how-we-reported-the-secret-irs-files?token=Et9-BFFxtA4W9ek9a6nnyQciZohsnG1D>

<https://www.verizon.com/about/news/quantum-computing-encryption-standards>

<https://www.top10vpn.com/research/covid-employee-surveillance/>

[https://www.reuters.com/world/europe/german-lab-eluthia-says-sus-](https://www.reuters.com/world/europe/german-lab-eluthia-says-sus-pends-use-bgi-prenatal-tests-privacy-probe-2021-07-12/)

<https://www.washingtonpost.com/technology/2021/10/14/apple-worker-scarlett/>

<https://www.theverge.com/2021/4/21/22395650/wyden-paul-fourth-amendment-is-not-for-sale-act-privacy-data-brokers-clear-view-ai>

<https://www.nytimes.com/2021/09/20/style/gabby-petito-case-tiktok-social-media.html>

<https://www.nytimes.com/2021/09/20/style/gabby-petito-case-tiktok-social-media.html>

Samp, DLA Piper-Tony, and Jim Halpert. "US and EU Pledge to Promote 'Innovative and Trustworthy' AI American and European Leaders Set the Stage for a New Era of Tech Cooperation to 'Update the Rules of the Road for a 21st Century Economy.'" *Lexology*, October 19, 2021.

<https://www.nytimes.com/2021/08/04/business/economy/amazon-union-labor.html>

<https://www.bloomberg.com/features/2021-capitol-riot-sedition-hunters/>

<https://www.washingtonpost.com/technology/2021/10/14/apple-worker-scarlett/>

Shen, Junzhu, and Tiejuan Zhu. "Seismic Noise Recorded by Telecommunication Fiber Optics Reveals the Impact of COVID-19 Measures on Human Activity." *The Seismic Record* 1, no. 1 (June 29, 2021): 46-55.

<https://www.reuters.com/technology/us-fcc-commissioner-wants-new-restrictions-review-chinese-dronemaker-dji-2021-10-19/>

Shi, Dai, Dan Tao, Jiangtao Wang, Muyan Yao, Zhibo Wang, Houjin Chen, and Sumi Helal. "Fine-Grained and Context-Aware Behavioral Biometrics for Pattern Lock on Smartphones." *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies* 5, no. 1 (March 29, 2021): 33:1-33:30.

https://newrepublic.com/article/163106/ddosse-creates-new-wikileaks-julian-as-sange?mc_cid=7fce136b2d&mc_ei

Selected Sources

d=abf5606579

<https://www.globaltimes.cn/page/202106/1225291.shtml>

Tangari, Gioacchino, Muhammad Ikram, Kiran Ijaz, Mohamed Ali Kaafar, and Shlomo Berkovsky. "Mobile Health and Privacy: Cross Sectional Study." *BMJ* 373 (June 17, 2021): n1248.

<https://www.technologyreview.com/2021/10/11/1036582/darren-byler-xinjiang-china-uyghur-surveillance/>

<https://themarkup.org/privacy/2021/09/30/theres-a-multibillion-dollar-market-for-your-phones-location-data>

<https://www.technologyreview.com/2021/06/09/1025884/coupan-gamazon-labor-costs-worker-death/>

"US State Privacy Legislation Tracker." Accessed November 5, 2021.

<https://www.theverge.com/2021/11/3/22761001/clear-view-ai-facial-recognition-australia-breach-data-delete>

lia-breach-data-delete

<https://www.natlawreview.com/article/virginia-becomes-2nd-state-to-adopt-comprehensive-consumer-data-privacy-law>

<http://theconversation.com/they-track-our-every-move-why-the-cards-were-stacked-against-a-union-at-amazon-159531>

<https://social.techcrunch.com/2021/09/09/what-chinas-new-data-privacy-law-means-for-us-tech-firms/><https://www.socialmediatoday.com/news/whatsapp-adds-another-layer-of-security-to-encrypted-chat-back-ups/608279/>

<https://gizmodo.com/a-wifi-network-can-be-used-to-accurately-count-how-many-1847688556>

<https://www.newscientist.com/article/2291357-simple-make-up-tips-can-help-you-avoid-face-recognition-software/>

<https://social.techcrunch.com/2021/10/06/european-parliament-backs-ban-on-remote-biometric-surveillance/>

<https://www.globaltimes.cn/page/202102/1216119.shtml>

<https://gizmodo.com/europe-wants-to-ban-facial-recognition-take-note-ameri-1847809788>

<https://techxplore.com/news/2021-06-artificial-tactile-skin-mimics-human.html>

<https://www.vice.com/en/article/m7qxwq/researchers-want-to-protect-your-selfies-from-facial-recognition>

<https://www.theverge.com/2021/7/14/22576236/retail-stores-facial-recognition-civil-rights-organizations-ban>

<https://www.prnewswire.com/news-releases/sensory-releases-speech-recognition-for-children-301392648.html>

<https://www.raconteur.net/healthcare/dna-screening-future-healthcare/>

<https://www.wired.com/story/algorithms-recognize-masked-face/>

<https://www.cnet.com/home/smart-home/alexa-isnt-the-only-thing-your-amazon-echo-can-listen-for-heres-what-else/>

<https://www.theverge.com/2021/4/14/22381370/automatic-gender-recognition-sexual-orientation-facial-ai-analysis-ban-campaign>

<https://www.zmescience.com/science/news-science/voice-mimicking-ai-dupes-alexa-and-other-voice-recognition-devices/>

<https://www.wsj.com/articles/apple-wants-iphones-to-help-detect-depression-cognitive-decline-sources-say-11632216601>



Metaverse, AR/VR & Synthetic Media

Trends shaping the future of business, work, entertainment, gaming, advertising, media, hospitality, government, health and other sectors.

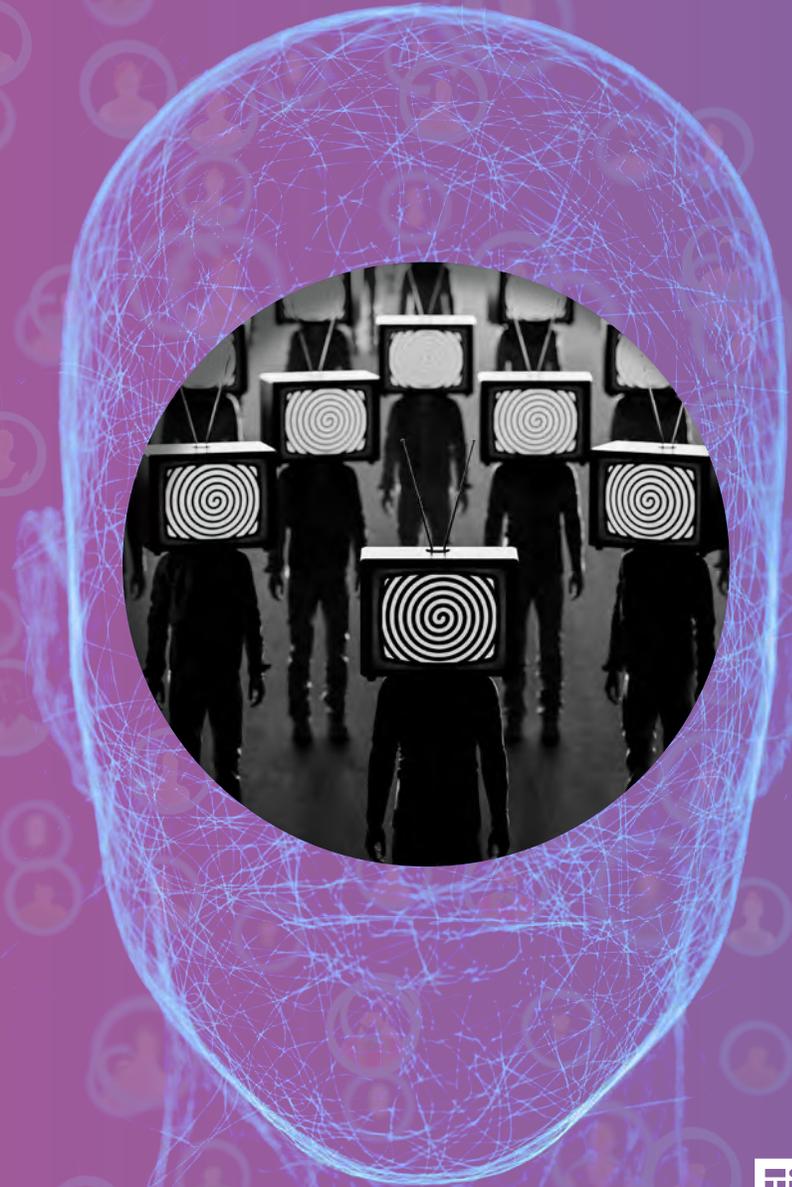


Table of Contents

153	Key Insights	176	Spatial Displays	187	Synthetic Media Policy and Regulation
154	Spaces	177	HMDs and Smart Helmets	187	Synthetic Media and Sexual Harassment
155	The New Realities Landscape	177	Holograms	187	Legal Frameworks for Synthetic Media
156	Digital Spaces	177	Holographic Data Storage	187	Using Synthetic Media to Skirt Copyright Laws
157	Digital Real Estate and the New “Neighborhood”	177	AR Cloud	188	Truth Decay in an Era of Synthetic Media
158	Scenario: Diminished Reality	178	WebAR/WebVR	188	Deepfake Detection
160	Digital Identities	178	Voice, Gesture, and Touchless Interfaces	190	Application
161	Avatars and Avatar Portability	178	Personal Device Ecosystem	191	Key Questions
162	Hyperrealistic Digital Personas	179	Synthetic Media and Content	192	Selected Sources
163	Fragmentation of the Virtual Persona	180	Synthetic Media		
164	Laws in the New Realities	182	Synthesis Tech		
165	Virtual Possessions and Ownership	182	Speech Synthesis		
166	Virtual Crime	182	Modulating Custom Voices		
168	Forensic AR/VR	182	Live Portraits		
169	Human Interfaces	183	Synthetic Places		
170	Smart Glasses	183	Liminal Spaces		
171	Smart Contact Lenses	183	Mapped Synthetic Environments		
172	Diminished Reality	184	Scenario: The Reborns		
173	AR for the Enterprise	185	Synthetic Media Business		
175	Hands-On to Heads-Up	185	A-List Synths		
176	Additional Metaverse, AR/VR & Synthetic Media Trends	185	Synthetic Media in Hollywood		
176	Volumetric Video	186	Synthetic Media Marketplaces		
176	Spatial Audio	186	Synthetic Media for Personalization at Scale		
		186	Synthetic Media in the Classroom and Workplace		

Key Insights

- * As of now, the metaverse is not a single technology, nor is it controlled by a single centralized company or entity.
- * People will create multiple digital versions of themselves, each tailored for specific purposes. This will lead to fragmentation—and a widening gap between who a person is in the physical world, and who they project in various online platforms.
- * The future of work will become more digitally immersive as companies deploy virtual meeting platforms, digital experiences, and mixed reality worlds.
- * As more users link their metaverse profiles to personal information like biometrics, data breaches could prove far more costly.
- * Smart eyewear, in the form of glasses and contacts, will upend industries and interfaces designed for smartphones.
- * Diminished reality (DR) will soon allow consumers to visually and audibly cancel whatever—and whom—ever—they wish, in real time.
- * WebAR and WebVR are part of a burgeoning field in which AR and VR experiences are accessible directly through a browser.
- * Online experiences are beginning to take place in virtual 3D environments that emulate those in the real world, from households and workplaces to event venues and retail shops.
- * The market for digital real estate in the nascent metaverse is subject to the same opportunities and pitfalls of any real estate rush.
- * Synthetic media marketplaces are virtual shops where users can commission, buy, and sell synthetic media, and even license their own attributes for use online and in the metaverse.
- * Synthetic media will be used to generate popular likenesses to deliver a range of personalized products and services at scale.
- * In the wrong hands, synthetic media can be a powerful and dangerous tool in spreading misinformation and disinformation.
- * Emerging technology tends to outpace the law, and synthetic media is no exception.
- * Brands that push beyond their current constraints will offer engaging products and experiences that could not exist in real life.



Spaces

The New Realities Landscape

With a growing range of virtual interfaces continuously evolving around us, it is critical that we draw distinctions between the various digitally mediated formats that span the reality-virtuality spectrum. Reviewing the intertwined definitions of the metaverse, AR, VR, MR, XR, and DR—with more Rs inevitably on the way—is the first step toward better understanding the future of the field.

The Metaverse

The metaverse refers to an all-encompassing virtual realm, incorporating various aspects of new realities in a sprawling, dynamic digital ecosystem. While definitions vary, today the metaverse is often described by two key features: It is persistent, meaning its collective network of 3D-rendered virtual elements and spaces is not turned on or off, but exists continuously and shared, meaning a vast number of users can access it simultaneously and interact within it. Some choose to see the metaverse as the evolution of the internet from a collection of pages, platforms, and apps to a world of 3D-rendered interfaces, viewed through smart eyewear. One thing is clear—the metaverse is not a single technology, nor is it controlled by a single centralized company or entity. It represents the gradual coming together of new and evolving tech, sensors and devices, and

high-bandwidth wireless network infrastructure, providing users with a new way to engage with each other and with the physical and digital worlds around them. Users can access the metaverse with avatars, virtual representations or extensions of themselves, and aspects of the metaverse can also bleed into our physical world. The boundaries between our physical world and the virtual metaverse may ultimately fall away as we come to view the physical and virtual as equally real.

AR vs. VR

Though both can be experienced via smart glasses or head-mounted displays, augmented reality (AR) and virtual reality (VR) are fundamentally different, and should be treated as such. AR makes digital alterations or additions to your existing environment, but you generally remain oriented to your physical surroundings. VR immerses you fully

in a virtual environment, one that is either artificially generated or emulates real-world surroundings other than your own. While they may share hardware, AR and VR each have unique applications, with enterprise and consumer use cases for AR eclipsing those for VR at present.

MR vs. XR

Mixed reality (MR) anchors virtual elements to corresponding physical elements in your environment—you can still physically interact with objects and surfaces, but their appearance and reactivity may be virtually altered or enhanced. MR experiences do not take place fully in the physical nor the virtual world, but in a hybrid of the two. Extended reality (XR) is more of an umbrella term that spans the reality-virtuality continuum, including AR, MR, and VR. XR overlaps with varying definitions of the metaverse.

DR Is AR

DR is AR, but not the other way around. Diminished reality (DR) is not fully immersive, leaving you anchored in your physical environment but with certain visuals, sounds, or other sensory elements suppressed. Thus, all DR is typically considered a subfield of AR—that does not mean, however, that all AR is DR.

Neal Stephenson coined the term “metaverse” in his 1992 novel “Snow Crash.”

1ST YEAR ON THE LIST

Digital Spaces



Digital spaces provide 3D-rendered environments for users' avatars to congregate, socialize, or work.

KEY INSIGHT

Online experiences are beginning to take place in virtual 3D environments that emulate those in the real world, from households and workplaces to event venues and retail shops. These digital spaces will serve as foundational in the metaverse as our online activities increasingly resemble our offline lives.

EXAMPLES

One of the first sectors to create shared online digital spaces was gaming, with sprawling interactive realms built to simulate environments, landscapes, and structures theoretically feasible in the real world. These gaming environments have recently diversified their offering to users, with platforms like Roblox and Fortnite hosting virtual concerts with big-name artists. In the context of business, Microsoft has previewed its Mesh product, due to launch in 2022, which will allow users to connect via the company's Teams communication platform by entering a 3D-rendered virtual workspace, rather than a standard video call. By applying mixed reality technology, Microsoft Mesh can also link elements of the virtual workspace to physical features of the users' actual surroundings, creating a hybrid physical-virtual environment.

DISRUPTIVE IMPACT

Soon digital spaces will be accessible for a broader range of activities, allowing users to have their avatars browse the shelves of virtual shops, enter virtual doctors' offices for remote consultations, and attend classes in virtual lecture halls, all with 3D spatial environments. As companies across all sectors develop strategies for extending their products and services to the metaverse, the creation of digital spaces will proliferate.

EMERGING PLAYERS

- Fortnite
- Meta
- Microsoft Mesh
- Nvidia Omniverse
- OpenSpace3D
- Roblox
- Spatial
- Unity
- Unreal Engine
- Wave

1ST YEAR ON THE LIST

Digital Real Estate and the New “Neighborhood”



As properties in popular virtual worlds sell for higher and higher record prices, speculators are eager to invest in this volatile but potentially high-return asset.

KEY INSIGHT

Though the metaverse is arguably infinite, shared spaces within it have finite boundaries and emulate traditional cities and towns. Some of these spaces are becoming popular hubs for virtual communities, gaming, commerce, and culture, giving rise to a digital real estate market in which users exchange currency to rent and own virtual property.

EXAMPLES

In an episode of HBO’s “How To With John Wilson,” the titular documentarian interviews a man who works as a “land baron”—essentially a virtual real estate agent—in the metaverse platform Second Life. The man explains how his avatar helps users tour and select properties in the platform’s virtual world, collects monthly rents, and even evicts delinquent tenants. As metaverse platforms attract more users (individuals as well as those with business interests) and integrate more functionality, new “neighborhoods” are taking shape around the same criteria that define their real-world counterparts: like-minded communities, property values, zoning codes, gentrification, strategic retail locations, and locally accessible services and cultural resources. The digital real estate market is booming as the metaverse rises in popularity—last November, a new record was set when digital real estate investors and developers Republic Realm purchased a plot in metaverse platform The Sandbox for \$4.3 million.

DISRUPTIVE IMPACT

The market for digital real estate in the nascent metaverse is subject to the same opportunities and pitfalls of any real estate rush. Savvy buyers may be able to snap up affordable properties now that eventually skyrocket in value, but this volatile market is best suited to investors with a high risk tolerance.

EMERGING PLAYERS

- Gala Games
- The Sandbox
- Metaverse Group’s Decentraland
- Republic Realm
- Somnium Space
- Spotselvie’s Spotland
- SuperWorld
- Upland

Diminished Reality • Mid-future pessimistic



HAS DIMINISHED REALITY LEFT YOU FEELING ALONE? WITHDRAWN FROM THE WORLD? WE CAN HELP!

Diminished reality (DR) is a great way to occasionally block out your surroundings to focus or find a little peace and quiet. But when used in excess, it can lead to desocialization and mental decline.

Symptoms include

Fear of others, loss of communication skills, and self-neglect

Trained professionals are standing by to help you take the first step toward recovery. This program gradually and painlessly weans you off DR and welcomes you back to a healthy, social lifestyle.



SCAN THIS AD TO CONTACT US NOW!

Paid for by the Metaversal Mental Health Initiative



Imagine if you came to New York when it was farmland, and you had the option to get a block of SoHo. If someone wants to buy a block of real estate in SoHo today, it's priceless, it's not on the market. That same experience is going to happen in the metaverse.

— Michael Gord, cofounder, Metaverse Group





Digital Identities

1ST YEAR ON THE LIST

Avatars and Avatar Portability



Avatars serve as the digital extensions or representations of users in online platforms, particularly in gaming, immersive social networks, and metaverse environments.

KEY INSIGHT

Avatars are virtual representations of users in digital platforms. As they become part of more people's everyday lives, avatar portability—the ability to transition an avatar between platforms built on different software or by different companies—will be key to creating a seamless user experience.

EXAMPLES

You might think of an online profile picture as the predecessor to an avatar, representing a user and appearing alongside content they post or records of their actions within a platform. The avatar brings this representation into greater dimension, often taking humanoid form, rendered in three dimensions, and capable of dynamic animated movement. In virtual environments with 3D perspective, these avatars can move around digital spaces and engage one another with voice, text, or by simulating physical interactions. As our online actions and behaviors transition from apps and websites to more immersive XR experiences in the metaverse, avatars will come to serve as our virtual emissaries for everything from shopping, to socializing, to working. Early efforts in avatar portability include a cross-platform avatar format called VRM from graphics company Khronos, which can be transferred across compatible VR platforms.

DISRUPTIVE IMPACT

Avatars will increasingly be used to not only represent a user in a virtual platform but as the main medium for how users interact and communicate. Avatar portability will allow users to move among various digital realms in the metaverse while maintaining a relatively consistent aesthetic and functionality in their avatar.

EMERGING PLAYERS

- Alethea AI
- Apple's Memoji and Animoji
- Khronos
- Meta's Codec Avatars
- Microsoft Teams
- Minecraft
- Roblox
- Stanford University's Virtual Human Interaction Lab

1ST YEAR ON THE LIST

Hyperrealistic Digital Personas



With hyperrealistic avatars, users can accurately re-create their likeness in the metaverse, allowing for remote communication that retains a greater sense of intimacy.

KEY INSIGHT

Avatars can be created in a variety of forms, but as users spend more time in XR and metaverse platforms virtually carrying out everyday tasks and interactions, there will be rising demand for avatars that can convincingly re-create their true human likeness.

EXAMPLES

Unreal Engine, a leading tool for generating 3D game visuals, launched its MetaHuman Creator in 2021. Users of the app, which promises “high-fidelity digital humans made easy,” choose from various templates to create highly customizable, hyperrealistic characters for use in games and virtual experiences, reducing a process that might previously have taken weeks to a matter of minutes. During the launch of Facebook’s rebrand as Meta, the company debuted its Codec Avatars, which use 3D-capture technology and artificial intelligence to efficiently create lifelike avatars for use in the sorts of metaverse environments that will play a central role in the company’s future business. Combining smart eyewear technology with hyperrealistic avatars will enable virtual interactions that approach the same level of intimacy as face-to-face engagement, and potentially allow users to replicate themselves in digital form and simultaneously occupy multiple virtual environments.

DISRUPTIVE IMPACT

Hyperrealistic avatars will allow users to accurately represent themselves in virtual environments and interfaces, helping to close the perceptual gap between remote and in-person communications. In the further future of the metaverse, hyperrealistic avatars will populate environments rendered with extreme realism, allowing virtual realities to accurately resemble our own.

EMERGING PLAYERS

- Epic Games
- Meta’s Codec Avatars
- Replica Studios
- Unreal Engine’s MetaHuman Creator

1ST YEAR ON THE LIST

Fragmentation of the Virtual Persona



Users tend to represent very different facets of themselves across various online platforms.

KEY INSIGHT

In the absence of standardized universal avatars, users of digital platforms are free to—and in many cases required to—create multiple online versions of themselves, each tailored to the virtual context it inhabits. These digital personas may range from representations of various facets of a user’s identity to entirely imagined characters.

EXAMPLES

A popular meme format features four pictures of the same celebrity displayed in a grid, each representing a different online platform: a wholesome, not particularly cool photo for Facebook; a clean-cut, buttoned-up headshot for LinkedIn; a youthfully edgy look for TikTok; and a flirty, smoldering portrait for Tinder. Despite the humorous intent, this meme reveals an important truth about online identities—we create different versions of ourselves for different corners of the internet. As more digital platforms adapt to the metaverse, and profile photos give way to more complex, dynamic avatars, this fragmentation of online identities will likely become more pronounced, as each of a user’s avatars lives a distinct virtual life, developing unique traits and behaviors in its given platform. This fragmentation can even take place in the opposite direction, where a single avatar is designed and influenced by multiple users, creating an even more complex relationship between humans and their virtual counterparts.

DISRUPTIVE IMPACT

Avatars are more than just digital stand-ins, and the way they are designed and controlled can have a psychological effect on their creator. In the longer term, the creation of multiple richly detailed online personas for individual users is liable to lead to a more pronounced fragmentation of their real-life identities.

EMERGING PLAYERS

- Social networks
- Avatar generators
- Game engines



Avatars are not just ornaments—they alter the identity of the people who use them.

— Jeremy Bailenson,
author, “Infinite Reality”



00

01

02

03

04

05

06

07

08

09

10

11

12

13

Metaverse, AR/VR & Synthetic Media

Laws in the New Realities

1ST YEAR ON THE LIST

Virtual Possessions and Ownership



NFT-backed virtual artworks have emerged as one of the most popular virtual possessions, and can theoretically be displayed on the walls of your digital space.

KEY INSIGHT

Virtual environments are evolving, and users are increasingly interested in acquiring digital possessions as investments and to enhance their profiles and experiences in the metaverse. New technologies are being applied to bestow these virtual items with the same qualities that make physical possessions valuable—uniqueness, scarcity, provenance—and provide a framework for digital ownership.

EXAMPLES

Virtual items—from clothing and furniture to tools and structures—can be created with 3D-rendering platforms, game engines, and other digital design applications, but for the item to exist as a possession in the metaverse, it must retain certain qualities beyond its aesthetic design. Blockchain and other ledger technology can be used to track a virtual item over time, authenticating it and logging its history as it changes hands and evolves, providing a basis for its valuation. NFTs, or non fungible tokens, can provide evidence of ownership for a virtual item or piece of digital content, even if it is easily reproducible. If you were to own an NFT of a unique 3D hat from a digital designer, for example, even though other users could copy its form and add it to their avatar, the NFT would ensure that data stored in a blockchain or similar ledger proves you are the sole owner of that particular item.

DISRUPTIVE IMPACT

Virtual possessions are evolving from art, collectibles, fashion, and real estate to items with unique added functionality in the metaverse, like art-related NFTs that pay a dividend to the owner when the related real-world work is sold or consumed, or that grant access to exclusive virtual environments.

EMERGING PLAYERS

- Alethea AI
- Aria Exchange
- Axie Infinity
- Dapper Labs
- Decentraland
- The Fabricant
- Foundation
- Mintable
- Rarible
- The Sandbox
- SuperRare
- Valuables

1ST YEAR ON THE LIST

Virtual Crime



A lack of comprehensive legal frameworks for XR and the metaverse may exacerbate the frequency and severity of cybercrime in emerging virtual environments.

KEY INSIGHT

Cybercrime, estimated to have led to the loss of trillions of dollars in 2021 alone, is expected to spread and evolve as web- and app-based digital interfaces transition to immersive virtual experiences in the metaverse, exposing new vulnerabilities.

EXAMPLES

Since the dawn of the internet, online actions have had the potential to damage users' reputations, livelihoods, bank accounts, and well-being in the real world. As those online actions become more personalized and immersive, the scope and complexity of cybercrime, as well as its repercussions, are expected to increase. Virtual currencies, especially those stored and exchanged on anonymized blockchains, are well suited for money laundering and illicit purchases. Deepfakes and hyperrealistic avatars can be used to falsely gain the trust of an individual and exploit them, particularly in metaverse workspaces. Bullying and harassment, already a scourge of social networks that has caused devastating real-world consequences for the victims, are likely to have an even deeper impact when insults and threats are delivered by avatars with real voices and animated 3D forms. Plus, as more users link their metaverse profiles to personal information like biometrics, data breaches could prove far more costly.

DISRUPTIVE IMPACT

Historically, tech companies have failed to take responsibility for crimes committed on their platforms. Thus, it is incumbent on lawmakers and cybercrime units to familiarize themselves with emerging virtual platforms if they hope to establish legal frameworks and law enforcement practices to make the metaverse safer for the average user.

EMERGING PLAYERS

- Harvard's Berkman Klein Center
- Interpol
- Law enforcement cybercrime units

I would be very surprised if five years from now the main association that almost anyone had with the metaverse was about the initial mention of it in Snow Crash.

— Mark Zuckerberg, CEO of Meta

1ST YEAR ON THE LIST

Forensic AR/VR



Augmented and virtual reality are useful tools for investigators in re-creating and analyzing crime scenes, and their insights have been used as supporting evidence in court.

KEY INSIGHT

Criminal investigations are evolving with the help of augmented and virtual reality tools, allowing analysts to re-create and explore destroyed or compromised crime scenes.

EXAMPLES

Australian forensic technology company Augmented Forensics uses photogrammetric image capture, 3D modeling, and AR and VR simulations to re-create crime scenes at 1:1 scale, giving investigators the opportunity to remotely walk through forensic scenes and analyze evidence, even after the environment has been altered. Forensic Architecture, a research agency based at Goldsmiths, University of London applies similar techniques with a focus on architecture and physical spaces, as it investigates human rights abuses and then shares its work with parliamentary inquiries, citizens' tribunals, and the U.N. In 2020, the agency 3D-modeled a scene at the Palestinian city of Hebron that couldn't be analyzed in person because of conflict in the region. Their model was then examined and used to corroborate testimony that an Israeli soldier had illegally beaten a Palestinian man at the site two years prior.

DISRUPTIVE IMPACT

Though AR and VR are useful forensic tools, their use in court as pivotal trial evidence will likely be controversial. Until the tech is widely accepted in the legal system, forensic AR and VR will serve mostly as an auxiliary tool for investigators.

EMERGING PLAYERS

- Augmented Forensics
- Forensic Architecture



00

01

02

03

04

05

06

07

08

09

10

11

12

13

Metaverse, AR/VR & Synthetic Media

Human Interfaces

5TH YEAR ON THE LIST

Smart Glasses



Smart glasses will be the successor to the smartphone as the primary personal device, and serve as a central technology for experiencing XR and the metaverse.

KEY INSIGHT

Resembling traditional glasses, but equipped with audio technology, cameras, and eventually smart lenses capable of displaying complex, dynamic visuals to the viewer, smart eyewear is poised to supplant the smartphone as the predominant personal device. If the future is the metaverse, smart eyewear is our primary way in.

EXAMPLES

Basic smart eyewear is already on the market, incorporating technology like voice assistants, touch-control surfaces, video capture, and bone conduction audio, which allows users to take calls and hear music and voice messages without putting hardware in their ears. These early-generation examples of smart eyewear, including Amazon's Echo Frames and RayBan's Stories, made in collaboration with Facebook (now Meta), are intended to familiarize the public with the devices, and potentially encourage early adopters who don't otherwise wear glasses to try out frames that have added functionality. But the long-term play will involve smart lenses, and serve as a wearable device for seamlessly experiencing XR and the metaverse. Meta has even begun developing what it calls "reverse pass-through" technology, which broadcasts live video of a user's eyes on the exterior of the smart eyewear lenses, allowing onlookers to see their full face even when the user is viewing immersive virtual content.

DISRUPTIVE IMPACT

Smart eyewear is expected to upend industries and interfaces designed for the smartphone by offering a more versatile and immersive hands-free alternative to the trusted mobile device. Eventually these devices will allow the metaverse to be ever-present in our everyday lives.

EMERGING PLAYERS

- Amazon's Echo Frames
- Apple's forthcoming smart eyewear product
- Meta's Project Aria
- Nreal Light
- RayBan Stories
- Snap Spectacles 3
- Vue
- Vuzix Blade

5TH YEAR ON THE LIST

Smart Contact Lenses



Smart contacts will allow people to experience augmented and diminished reality without having to wear glasses.

KEY INSIGHT

Smart contact lenses, embedded with sensors and electronic components, can display text and images. Some can make real-time adjustments to help people with presbyopia (the loss of the eyes' ability to focus on very near objects, such as a restaurant menu).

EXAMPLES

Several companies have developed smart contact lenses that act as a heads-up display for wearers. Mojo Vision developed a heads-up display specifically for athletes. Partnering with a host of companies, including Adidas (running), 18Birdies (golf), and Wearable X (yoga), Mojo Vision is developing a new type of wearable interface for sports training. So, runners could see their metrics, such as pace and distance, in their field of vision without having to glance down at a watch. Golfers could see the angle of their club and likely trajectory of the ball. InWith Corp. developed a soft contact lens that connects wearers to important, real-time information that they would normally try to find on their phone—such as speed limits and maps—but they could safely do so while driving. The company is also developing a soft contact lens that could eliminate the need for multifocal lenses and reading glasses.

DISRUPTIVE IMPACT

Smart contact lenses must gain U.S. Food and Drug Administration approval before heading to market. Once they do, there could be a profound impact on athletics and personal training, as wearers gain a potential competitive advantage over others. Sports leagues and competition hosts will need to determine whether smart contact lenses should be allowed during competition. Smart contact lenses are a new interface—which means that content creators, game developers, and UX designers will have an entirely new playground to explore.

EMERGING PLAYERS

- Mojo Vision
- InWith
- Form
- Innovega

2ND YEAR ON THE LIST

Diminished Reality



Removing ads from one's field of view is one of the many potential applications of diminished reality.

KEY INSIGHT

As smart glasses proliferate and AR becomes commonplace over the next decade, diminished reality (DR) presents an opportunity to virtually mask, reduce, or suppress features of one's environment, rather than simply build on top of it. While the metaverse is commonly thought of as adding stimuli to our surroundings, DR may enable a more minimalist approach.

EXAMPLES

DR has existed in some form for over a decade, with one of the most ubiquitous examples being noise-canceling headphones. But as the technology matures and is developed for the audiovisual applications of smart eyewear, users will be able to target specific environmental elements that they want to suppress, such as isolating a specific speaker's words and appearance in a crowded room, or removing all advertising from view as they walk through a city center. But there are also therapeutic applications for those with unique sensitivities, such as PTSD sufferers. One study published by the Institute of Electrical and Electronics Engineers outlines a series of experimental workshops that used DR to assist individuals on the autism spectrum "who are adversely affected by continuously changing surroundings or distracting visual incidents."

DISRUPTIVE IMPACT

Diminished reality forces us to rethink how digital mediation can shape our surroundings by subtractive rather than additive means, improving quality of life for a broad range of users, but not without risks.

EMERGING PLAYERS

- Amazon Sumerian
- Apple's ARKit
- ARToolKit
- Google's ARCore
- Vuforia Engine
- Wikitude

5TH YEAR ON THE LIST

AR for the Enterprise



With augmented reality applications, architects and designers can collaboratively build and view interactive digital twins of their work with precise detail.

KEY INSIGHT

From factory floors to virtual meeting rooms, AR has a broad range of business applications, fueling accelerated investment and growth in the field, and the development of workspaces in XR and the metaverse.

EXAMPLES

Microsoft's HoloLens 2 head-mounted display (HMD) was designed specifically with business solutions in mind, incorporating cloud and AI functionality, interoperability with industry partners, and a suite of developer tools. The device has already been adapted for the U.S. Army, enabling holographic training modules and the projection of 3D terrain maps within the user's field of vision. Smart eyewear and HMD maker Nreal announced new enterprise editions of its mixed reality devices in 2021 aimed at the manufacturing, retail, tourism, education, logistics, and automotive markets. Users can operate the headsets in conjunction with a wearable ring controller from spatial tracking company Finch Technologies and control their movements through hand gestures. The uses of business-focused AR headsets are wide-ranging, encompassing everything from monitoring supply chains and complex equipment via digital twins, to hosting remote meetings in 3D, to providing guided AR tutorials as part of workplace training.

DISRUPTIVE IMPACT

Companies of all sizes and industries should be asking themselves where AR can be implemented to streamline and enhance functions and processes throughout the organization. AR devices are now being offered as part of a larger ecosystem, compatible with third-party operating systems and developer kits that allow smaller companies to plug in to existing systems, while bigger companies can design and customize their own.

EMERGING PLAYERS

- Atheer
- CAE
- Finch Technologies
- GigXR
- Hevolus
- Kognitiv Spark
- Medivis
- Nreal
- PTC
- Scope AR
- Spatial
- Trimble
- Ubimax
- Upskill



Using a blend of physical and behavioral biometrics, emotion recognition, sentiment analysis, and personal data, the metaverse will be able to create a customized and enhanced reality for each person.

— Melanie Subin, Director, Future Today Institute



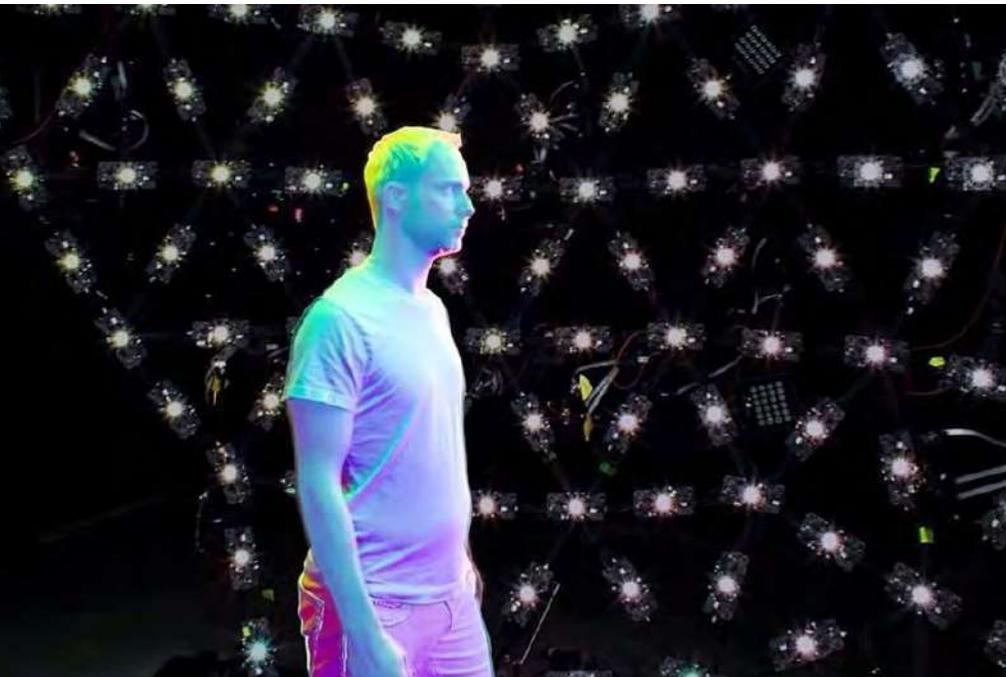
Hands-On to Heads-Up

With sales of smartphones plateauing, and upgrades to their functionality arguably growing less substantive with each new iteration (How many cameras does a phone actually need? Is a folding screen really that useful?), the era of handheld device domination seems to be coming to a close. It might be hard to believe at the present moment, but a suite of devices is already in development that is strategically positioned to unseat the mighty smartphone as the primary personal device. Central among them is smart glasses, the long-awaited wearable that gives the average user access to on-demand data overlays and a rich array of augmented and virtual realities, without ever having to lift a finger.

With conversation about the metaverse at a fever pitch, it's no wonder that tech giants from Apple to Amazon have invested years of research and development into smart glasses, the key to unlocking this nascent virtual ecosystem. Powered with advanced voice assistant technology, as well as touchless gesture control, these smart glasses—along with a selection of other wearable digital accessories—will establish a new paradigm in how humans interact with our personal technology. Instead of constantly staring at a smartphone screen, we will free up our hands for other tasks as we take in text, audio, video, and virtually rendered content without ever having to lose sight of the world around us. By layering digital elements into our field of vision, these devices will enable a revolutionary and liberating transition from hands-on to heads-up computing.



Additional Metaverse, AR/VR & Synthetic Media Trends



Computer scientists at Google are developing volumetric capture technology to blend the physical and digital worlds together.

■ Volumetric Video

A pivotal technology for developing XR experiences and environments in the metaverse that emulate real spaces, volumetric video is the capture of a space, figure, or event in 3D. The resulting video can then be viewed either on a screen or XR device. While viewers of 360-degree video can rotate their perspective and see the full scope of their surroundings from a fixed point, volumetric video, which is also related to holographic technology, allows viewers to pivot around their subject, viewing it with depth, and from all angles. Microsoft's Mixed Reality Capture Studios are an international network of certified facilities for capturing volumetric video intended for MR applications. Once smart eyewear is the norm, we will come to expect content to be experienced volumetrically, rather than the flat perspective offered by smartphone, tablet, and desktop screens.

■ Spatial Audio

Just like volumetric video gives perspective and depth to visual content, spatial audio is broadcast in such a way that the listener interprets the sounds as occupying various spaces in their environment. The latest editions of Apple's AirPods feature spatial audio technology—when it is activated, sounds are perceived in relation to the listener's positioning as well as the positioning of the source device. For example, if you're watching an action film on your phone and you turn your back to it, an explosion in the film would then be heard from behind you, rather than before you. Similarly, when you move the phone but keep your head still, the auditory perspective shifts with the positioning of the device. This technology will be central to creating lifelike sensory experiences in XR and in the metaverse.

■ Spatial Displays

Spatial displays offer the magic of virtual reality without having to strap on a head-mounted display. Instead, a flat screen projects objects in what looks like a hyperrealistic, three-dimensional diorama. Spatial displays use high-speed face and eye-tracking cameras to always detect the position of the viewer's eyes in real time. A video generation algorithm responds to the viewer's eyes, while tiny lenses deliver stereoscopic images to each eye. Sony's Spatial Reality Display debuted in 2020 with a dedicated software development kit supporting Unity and Unreal Engine 4. With a price tag of about \$5,000, this technology is currently aimed at designers, architects, and marketers. But as spatial displays improve and mature, they will change how we watch movies, test-drive vehicles, and attend board meetings. It will give doctors a way to show their patients what's going on

Additional Metaverse, AR/VR & Synthetic Media Trends

inside their bodies in 3D, while history teachers could take students on immersive tours of ancient ruins.

■ HMDs and Smart Helmets

Head-mounted displays (HMDs), which offer more robust functionality than smart glasses but are too cumbersome and restrictive for casual use on the go, are more commonly used in controlled workplace environments or for mostly stationary entertainment and gaming. Popular HMDs currently include the Meta (formerly Oculus) Quest 2 and Microsoft HoloLens 2. Smart helmets, protective headwear integrated with augmented reality visors and other connected technologies, have been available to U.S. Air Force pilots for years—the F-35 helmet, for example, is equipped with noise-canceling headphones, night vision functionality, and a projector that can broadcast live video on the inside of the helmet's visor.

Smart helmets like the Crosshelmet for motorcyclists are now available on the consumer market as well, offering features like AR navigation displays and voice assistant technology.

■ Holograms

Holograms are light field recordings that, when reproduced, can appear as static or dynamic three-dimensional visuals. The term is also more generally applied to any image that is rendered to appear in 3D. The accurate digital reproduction of faces, bodies, and other complex structures in dynamic 3D form is critical to the evolution of AR and VR in the metaverse, and holograms, variously combined with deepfake technology and synthetic media, may soon inhabit our everyday environments. Holograms have been used to produce concert tours featuring bygone stars in virtual form, and may soon allow production companies to draw popular synthetic

media characters, celebrity stand-ins, brand spokespeople, historical figures, and lost loved ones out of our screens and into our spatial environment. In the medical field, holographic mapping can provide doctors with a 360-degree view of a patient's internal organs, vessels, bones, and tissue and assist with diagnostics and surgeries, with multiple apps already approved by the U.S. Food and Drug Administration. As it evolves, this technology may be used to display elements of the metaverse without users having to wear smart glasses.

■ Holographic Data Storage

Though still in the R&D stage, holographic data storage is a promising potential technology for storing data in the volume of the recording medium, rather than on the surface, as in optical and magnetic data storage. In theory, this creates a new form of ultra-high density data storage, allowing massive amounts

of data to be stored in a compact form. In the case of Microsoft's Project HSD, launched in 2020, the proposed holographic storage device incorporates a crystal, through which light can be broadcast to create a range of unique holograms, each one holding hundreds of kilobytes of data. The technology, if successfully developed, could greatly improve the efficiency of data storage infrastructure, and Microsoft intends to use holographic storage devices as components of its Azure cloud computing service.

■ AR Cloud

AR cloud technology seeks to populate the physical world with shared digital elements that can be viewed through devices like smart eyewear. What distinguishes AR cloud from the more inclusive category of augmented reality is that AR cloud content is persistent, rather than intermittent or temporary,

and it is shared, meaning anyone with the proper device can view it, and the experience will be more or less universal across devices. For example, a crowd of tourists walking down a city street wearing smart glasses might all see the same AR cloud content as they pass by different buildings—a virtual plaque on a historic schoolhouse, a 3D menu at the door of a restaurant, or an animated mascot beckoning passersby into a movie theater. The content occupies the same physical space no matter what angle it is being viewed from, and is always present in its digital form, whether or not an audience is watching. AR cloud technology shares the same persistent and shared aspects that define the metaverse, and will play an important role in the sprawling virtual ecosystem as it evolves.

Additional Metaverse, AR/VR & Synthetic Media Trends



Researchers at the University of British Columbia's The Hive use WebAR to display holographic brains for use in medical school classes.

■ WebAR/WebVR

The majority of AR and VR experiences available today require users to download an app to their device, but WebAR and WebVR are part of a burgeoning field in which AR and VR experiences are accessible directly through a browser. This successfully sidesteps the data storage limits and device compatibility issues that might hinder an app-based experience, effectively helping the AR or VR content reach a broader audience more efficiently. The field is still in its infancy, but promises to create a new paradigm for AR and VR that is more inclusive and immediately available, and makes aspects of the metaverse accessible to those without next-generation devices.

■ Voice, Gesture, and Touchless Interfaces

If physical buttons and screens become a thing of the past, how will we control and communicate with our devices and the virtual world around us? The proliferation of voice assistants, from Google Home to Amazon Echo, in households across the world represents more than just a new level of convenience for families and individuals. The devices are also a method of capturing massive amounts of voice data to develop the next generation of voice AI, which is expected to understand nuanced language and communicate far more fluently, and allow users to interact with devices and virtual interfaces hands-free. In addition to voice commands, touchless interfaces will be navigated through the use of gesture, where a user's physical movements are tracked and interpreted

to control a device or projected display. Instead of dragging a fingertip across a physical screen to browse content, for example, users could motion with their head or wave their hand in the space in front of them and have their smart glasses scroll through a virtual display accordingly.

■ Personal Device Ecosystem

Since the rise of the smartphone in the late 2000s, it has cemented itself as the predominant personal device, and a defining technological touchstone of the last decade and a half. But as the internet evolves and the metaverse takes shape, a new suite of devices will replace and expand the functionality of the smartphone, with hands-free hardware and next-generation interfaces becoming more seamlessly integrated into our everyday lives. Smart eyewear

will play a key role in this personal device ecosystem, taking over many of the functions currently offered by smartphones, and a number of additional devices, including smart watches, rings, gloves, cuffs, and skinterfaces will together enable more complex and precise methods of tracking and interacting with ourselves, each other, and our surroundings. In addition to freeing up our hands, these devices will capture biometric data and use AI to create nuanced profiles of users' mental, physical, and emotional states.



00

01

02

03

04

05

06

07

08

09

10

11

12

13

Metaverse, AR/VR & Synthetic Media

Synthetic Media & Content

3RD YEAR ON THE LIST

Synthetic Media



As advances in synthetic media technology make it easier to render realistic looking human likenesses, it's getting harder to tell if the person you're looking at is a person at all.

KEY INSIGHT

Synthetic media consists of algorithmically generated digital content, including audio, video, deepfakes, virtual characters and environments, and more. The technology will become an integral aspect of future XR experiences in the metaverse.

EXAMPLES

Synthetic media is created using artificial intelligence. Algorithms use an initial set of data to learn—people, voices, photos, objects, motions, videos, text, and other types of media. The end result is realistic-looking and realistic-sounding artificial digital content. Voice clones, dynamic voice and facial skins, unique gestures, videos, and interactive bots are all part of the ecosystem. Synthetic media can be used for practical reasons, such as generating characters in animated movies, creating avatars for use on digital platforms and in the metaverse, or acting as stand-ins for live action talent. The diverse potential applications of synthetic media have attracted entrepreneur Mark Cuban, who has made significant investments in the sector through companies like AI video generation platform Synthesia and Alethea AI, which is combining aspects of synthetic media and ledger-backed token technology to create what it's calling “intelligent” NFTs, unique AI-powered avatars that the company will host in its metaverse platform.

DISRUPTIVE IMPACT

Watch for synthetic media to edge more into the mainstream in 2022, representing new opportunities and risks for businesses; reshaping the entertainment, news, service, social and communications landscape; and providing dynamic new forms of content in the nascent metaverse.

EMERGING PLAYERS

- Hour One
- Wolf3D
- Samsung Next
- Loudly
- Endel
- Replica Studios
- Lovo
- Modulate
- Rephrase.ai
- Synthesia
- Alethea AI
- Carv3d
- Animatico
- Narrativa
- DeepNatural
- Baidu Research



That is already a real-world harm that deepfakes are having, even before they become ubiquitous. People are starting to question the authenticity and veracity of authentic media, which is pretty devastating in a world where trust in digital media is absolutely essential for society and politics functioning.

— Nina Schick, author, “Deepfakes”



Synthesis Tech



Deep Nostalgia tech from MyHeritage uses AI to animate photos, creating what seem like living portraits.

■ Speech Synthesis

Also known as “synthetic speech” or “text-to-speech technology,” speech synthesis mimics real human voices and deploys them to various interfaces. With enough data and training, a speech synthesis system can learn the spectral frequency of anyone’s voice and produce someone’s digital voiceprint. The tech can be used for nefarious acts, such as impersonating a trusted figure in an audio conversation to extract sensitive data or make a false request. In 2021, researchers at the University of Chicago’s Security, Algorithms, Networking and Data Lab tested two publicly available, open-source speech synthesis algorithms and were able to dupe voice recognition software from Microsoft, WeChat, and Amazon to access users’ devices by artificially re-creating their voices. Speech synthesis can also be used for more decent, thought-pro-

voking pursuits, as when MIT’s Center for Advanced Virtuality and Ukrainian startup Respeecher contributed to an “interactive documentary” by generating Richard Nixon’s voice reciting a never-before-heard speech prepared in case the Apollo 11 mission failed—called “In Event of Moon Disaster,” the short film won an Emmy last year. Another company, Synthesia, uses this technology to dub people through automated facial reanimation. This will be especially useful for movies with wide, international releases. Actors’ facial expressions and mouths can be reformatted to ensure local languages are correctly synchronized.

■ Modulating Custom Voices

Generative algorithms are creating synthetic voices that sound just like the original, and those voices can be modulated to the exact pitch and tone desired.

The AI learns over time to recognize not only intonation but also emotional cadences. Replica Studios, Lovo, Voice-mod, Resemble Ai, DeepZen, Sonantic, VoiceID, and Descript synthesize voices for a host of purposes. For example, you can fake a conversation between yourself and your favorite celebrity, provided there are enough publicly available audio files of that celebrity to build a dataset. Soon, the technology will be able to match and rapidly deploy synthetic voices personalized for every consumer. In one context, a user might hear the comforting voice of a departed loved one or a playful voice from their favorite childhood cartoon. In this era of misinformation, however, we must also beware the use of synthetic voices to influence or mislead unwitting consumers.

■ Live Portraits

In the imaginary universe of “Harry Potter,” the halls of Hogwarts are hung with framed portraits of past wizards that can move and speak with living observers. Now, with the help of AI, this style of “live portrait” is making its way into the real world. MyHeritage, a genealogy platform, has employed facial recognition and mapping technology from Israeli startup D-ID to offer a feature that synthetically animates faces from old photos. Members of the site can apply the technology to old family photos or those already in the platform’s database to create brief synthetically generated videos of the long-departed appearing to smile, blink, and rotate their heads with eerily lifelike accuracy. D-ID’s latest magic trick? Allowing users to animate these live portraits with their own facial expressions, and even create the illusion that the portrait is speaking words of the user’s choosing.

Synthetic Places



The Shed's AR exhibition featured art from KAWS.

■ Liminal Spaces

Extended reality is blending the physical and digital realms, transforming real-world spaces into interactive environments. These new experiential spaces make use of sensors, smart cameras, real-time mapping, augmented reality, and other technologies so that digital elements can respond to people as they move. For example, Artechouse produces interactive installations at its Miami Beach, New York City, and Washington, D.C., locations. In a spring 2022 exhibition, an artist used generative algorithms to create audiovisual paintings—imagine swirling colors and sound—while visitors watched and listened. The Shed partnered with High Line Art in New York City to develop “The Looking Glass,” where visitors used an app to see virtual statues dotting the High Line’s walkway and interactive soundscapes turned on as visitors moved past.

■ Mapped Synthetic Environments

Companies, agencies, and organizations are now mapping the real world to generate synthetic digital twins. The U.S. Army Research Laboratory has set out to build One World Terrain, an up-to-date, high-resolution 3D map of the world that can be used for positioning and navigation on the ground in territories where GPS cannot be accessed. The nearly \$1 billion project, contracted to a subsidiary of satellite operator and 3D-mapping company Maxar Technologies, is central to the Army’s Synthetic Training Environment, a hybrid physical-digital interface for soldiers to run training missions in immersive virtual settings that mirror the real world. On the corporate end of mapped synthetic environments, Amazon built synthetic simulations of the roads, buildings, and traffic of Snohomish County in Wash-

ington, reportedly accurate down to the centimeter. The company fused maps and 3D data to build a synthetic clone of the county and then tested its Scout delivery robot in the real-world environment there, having trained it in the synthetic version.

The Reborns • Mid-future pessimistic scenario

The Samuel-Clark Nurseries

You'll never forget how little she was.

They grow up too fast. Before you know it, your darling baby is a teenager and then, overnight, a grown woman. Now, you have the opportunity to preserve your baby forever.

Introducing the Forever Young collection from Samuel-Clarke.

Using our exclusive spatial mapping technology, our artists will create a physical replica of your little one at birth, with real-feel™ skin, synthetic nails on your baby's delicate fingers, and a deep-replica™ voice.

She is responsive to your touch and the sound of your voice. Sing her bedtime songs and listen

to her coo. If a stranger picks her up, she'll cry out for her parents.

You can't really appreciate how lifelike she is until you pick her up and hold her. When you cradle her in your arms and gaze into her eyes, you'll swear that she is real. Save all those baby clothes so that you can change her nappies and dress her up in your favorite onesies and dresses.

Your Forever Young baby is waiting for you, for only six easy installments of \$29.99*. Your satisfaction is guaranteed, so please order today.

The Samuel-Clarke Nurseries
 Forever Young Collection
 P.O. Box U-203912
 Bloomington, Illinois 60721-3827

YES! I would like to preserve the memory of my precious little one! I understand that I need to send **NO MONEY NOW.**

X _____	
Signature _____	Date _____

Address _____	City _____

State _____	Zip Code _____

*Plus \$299 spatial mapping fee, \$99 synthetic voice generation fee, \$49 delivery, and sales tax where applicable.



Only 6 easy installments of **\$29.99***

Synthetic Media Business



Sensorium Galaxy allows users to enter a series of virtual worlds where they can watch musical performances and interact with others using an avatar.

■ A-List Synth

With the spread of AI-generated media, a new crop of synthetic celebrities has emerged. Occupying the same cultural roles as their real-world predecessors—singers, models, influencers, brand ambassadors, etc.—these virtual stars afford a host of opportunities to make and save money, and are likely to play a big part in the emergence of new forms of content and pop culture in the metaverse. At the forefront of the synthetic celebrity scene is Lil Miquela, who inhabits the persona of a perpetually 19-year-old girl and has amassed millions of followers on social platforms including Instagram, Snapchat, and TikTok since she first appeared in 2016. She’s been pictured with real-world celebs like Diplo and Millie Bobbie Brown, partnered with brands from Calvin Klein to Samsung, released singles on music streaming platforms, and has even been depicted as publicly grappling with the existen-

tial quandary of her own existence and awareness of being a synthetic creation. Her appearance and behaviors have been designed, rather than algorithmically generated, by a team of engineers at startup Brud (recently acquired by NFT and blockchain company Dapper Labs), which plans to hand some control of Lil Miquela’s image and behaviors to her followers and fans—a clear sign of how synthetic media can expand the definition, function, and role of celebrity. Additional virtual influencers include Knox Frost, who partnered with the World Health Organization to deliver pandemic safety messages; Lu Do Magalu, who’s been around for over a decade and posts popular unboxing videos and product reviews; and the synthetic girl group NPC, created by musician Grimes, which consists of “infinite members” who can be voted in or out by fans. Since these synthetic stars don’t need food or sleep, they can work around the clock and be customized and

scaled for countless applications and endless content, making them valuable assets for their creators and various stakeholders, and a major component of the emerging metaverse-oriented media industry.

■ Synthetic Media in Hollywood

From Michael Keaton in “Multiplicity” to Tom Hardy in “Legend,” Hollywood has already experimented with multiple iterations of the same actor appearing on screen simultaneously, but with synthetic media, the possibilities are endless. An actor could interact with countless versions of herself in a scene, and only have to shoot once—or not at all. An aging Hollywood star could license out a synthed version of their younger self to be cast in a new film. An up-and-comer could costar with their idol, who died decades before they were born. Sound far-fetched? Synthetic media’s already starting to make its way onto the big screen. In 2020’s “The Mid-

Synthetic Media Business

night Sky,” the actor playing a younger version of George Clooney’s character spoke with a synthed, Clooney-inflected voice, and in “Roadrunner,” a documentary about the late Anthony Bourdain, the celebrity chef’s voice was synthed to re-create quotes for which no extant audio existed, a controversial move that left many viewers feeling uncomfortable and misled.

■ Synthetic Media Marketplaces

So where do you go if you want to use a synthetic avatar or character but don’t know how to build one yourself? The answer is synthetic media marketplaces, virtual shops where users can commission, buy and sell synthetic media, and even license their own attributes for use online and in the metaverse. Some of these platforms, like those established by startups Alethea AI, Hour One, and Wolf3D, allow users to develop realistic synthetic avatars of themselves for use

in virtual platforms and games, create unique synthetic characters, or pay to use synths—either based on real people or artificially generated—in creative content, presentations, or professional settings. Others, like the unofficial marketplace that first popped up on Reddit in 2018, are less legitimate and function more like black market trading posts, where users can exchange cryptocurrency for deepfake videos of celebrities, coworkers, family members, neighbors, enemies, and more.

■ Synthetic Media for Personalization at Scale

Founded in 2017, the personalized greeting app Cameo has made a name for itself by connecting public figures of varying levels of fame to average individuals—pay a fee, and the celeb (or B-lister) will record and deliver a personalized message to the recipient, whether it be a birthday greeting, pep

talk, or apology, on behalf of the sender. But as the app grew, so too did its selection of celebrities to choose from. In 2021, Cameo added a new talent to its ranks: the titular star of hit animated film “The Boss Baby.” Partnering with DreamWorks Animation, synthetic video startup Hour One, and synthetic speech startup Lovo, the app was able to offer custom messages delivered by the character, complete with the synthed voice of Alec Baldwin, who voices the Boss Baby in the film and its sequel. Though it may be simply a playful innovation for now, this application of synthetic media tech signals a future where popular likenesses could be created to deliver a range of personalized products and services—imagine having a world leader as a virtual personal assistant, a rockstar dedicating a song to each of her millions of fans by name, or even a star-studded film with plot and dialogue curated specifically to each viewer’s tastes.

■ Synthetic Media in the Classroom and Workplace

Despite understandable concern about the effects of deepfakes and synthetic media “in the wild,” the technology has potentially beneficial applications, particularly in the classroom and workplace. Text-to-video startup Deep Word offers synthetic videos of actors or self-uploaded personas that recite scripts generated by the user. Among the top suggested uses of the videos are academic lectures, presentations, and corporate training, and the content can be automatically translated and visually altered to have speakers deliver their message in a range of languages. The ability to customize lessons and workshops at scale for a range of audiences and learning styles can greatly improve the impact and effectiveness of video content, improving the performance of students and workforces at low cost. Elsewhere in the corporate context,

partners of professional services company EY have reportedly begun using synthetic media to communicate with clients rather than engaging with them personally. The technology enables these partners to connect with multiple clients in various languages at scale, and viewers are always informed that they are watching artificially generated content rather than a traditional recording of a human.

Synthetic Media Policy and Regulation



New legal frameworks governing the metaverse will be discussed this year.

■ Synthetic Media and Sexual Harassment

According to research company Sensi AI, approximately 90%–95% of all deepfake videos fall into a particularly dubious category: nonconsensual pornography. Deepfakes actually originated in this questionable genre, first popping up on discussion site Reddit in 2017. Early targets for synthetic sex tapes were celebrities, many of whom have ample public video content to use as source material, and plenty of “fans” eager to view the results. But the technology to create a nude version of someone’s likeness has become more accessible, with apps like DeepNude popping up before quickly getting banned on most legitimate platforms. The result is that deepfake tech can now be used to create and share synthetic sex tapes of average individuals, a potentially devastating experience for the victims, who are almost exclusively women. These videos constitute a new form of “revenge porn,”

explicit content shared expressly to harm the subject, and a type of content banned in 46 U.S. states. But the law has been slow to address the use of synthetically generated revenge porn—only two of those states’ bans include deepfaked media.

■ Legal Frameworks for Synthetic Media

Emerging technology tends to outpace the law, and synthetic media is no exception. While research engineers race to develop methods to detect synthetically altered content and identify any malicious actors who might have created it, the question remains: Even if we catch the perpetrators, what crimes can they be charged with? Are any laws on the books that definitively apply to synthetic media? Last August, a group of U.S. senators aimed to address that question by proposing a National Deepfake and Digital Provenance Task Force.

The group, which would operate under the Department of Homeland Security, marks one of the first federal legislative actions in the nation to securely assess the origins and chronology of images, videos, audio, and other digital media content. Elsewhere, Norway passed a law in 2021 that requires social media influencers to disclose when images shared from their accounts have been altered, specifically with regard to the shape and size of bodily features, and Australia’s Code of Practice on Disinformation, meant to curtail the spread of manipulated media, has been adopted by major tech companies including Google, Facebook, TikTok, and Twitter.

■ Using Synthetic Media to Skirt Copyright Laws

Among the many legal quandaries emerging around synthetic media, copyright law is a recurring theme. In the past, copyright law has made it illegal to

Synthetic Media Policy and Regulation



“Cheapfakes” and “shallowfakes” aren’t sophisticated—but they are creating problems.

create and share a direct copy of a piece of media—a photograph, music album, or televised broadcast, for example. But what happens if artificial intelligence is used to synthetically re-create the content so accurately that the difference is imperceptible to humans? That might not technically constitute a copy, though it could effectively function as one. The resulting content, indistinguishable from the original, in theory could legally be presented to the public at a discount or for free, drastically undermining the owner’s or creator’s control over their work and ability to monetize it. An AI system could even be trained to recognize the precise legal boundary where a piece of synthetic content infringes on copyright laws, then generate the content right up to that limit, maximizing the resemblance while staying just within the bounds of the law. On an international level, these issues are being addressed by the U.N.’s World Intellectual Property Organiza-

tion, which is engaging stakeholders in member states to discuss the effects of AI on intellectual property.

■ Truth Decay in an Era of Synthetic Media

With the advent of synthetic media comes the end of the premise that seeing (or hearing) is believing. Tech companies big and small are working on technology that can reliably detect when a piece of content has been synthetically generated, but until then, the general public is susceptible to being duped into thinking synthetic media simulating a familiar likeness is the real thing. For the time being, public exposure to synthetic media is mostly limited to device screens, via social media platforms, private messaging apps, video chat portals, and other virtual interfaces. But even now there are risks, as deepfakes—and even “shallowfakes” or “cheapfakes,” rougher,

easily generated versions of their more sophisticated counterparts—can be weaponized to spread misinformation and “fake news,” falsely incriminate or humiliate unwitting individuals, and artificially influence political elections on platforms where algorithms drive users to share and engage with sensationalized content without necessarily verifying its authenticity. Once the metaverse proliferates and users can encounter synthetic media seamlessly integrated into their everyday lives and interactions, these threats become even more pervasive.

■ Deepfake Detection

As AI is used to generate increasingly sophisticated deepfakes indistinguishable from unaltered media, those looking to protect the public from being misled by synthetic media are fighting fire with fire, deploying AI-powered filters to detect and flag synthetically

modified content. In 2021, collaborative efforts from research engineers at Facebook (now Meta) and Michigan State University were cited as an advancement in deepfake detection technology, with the embattled social media giant (embattled, among other reasons, for the rampant spread of misinformation on their own platform) claiming it could now better identify deepfaked images, and even determine their origin through reverse engineering. Additional approaches, from photo and video verification startup Truepic to Google’s societal threat research unit Jigsaw, are being tested to help mitigate the risks of synthetic media and deepfakes, risks that will grow in scope and severity as the technology evolves.



Problems are already surfacing. Avatars, the graphical personas people can create or buy to represent themselves in virtual environments, are being priced differently based on the perceived race of the avatar, and racist and sexist harassment is cropping up in today's pre-metaverse immersive environments.

— Breigha Adeyemo, Doctoral Candidate, University of Illinois at Chicago

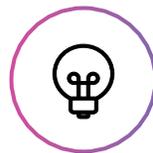


How these trends impact your company



STRATEGY

As the metaverse develops and new reality technologies advance, there will be a number of competing platforms (and corporate interests). The political challenges wrought by web 2.0—lawmakers wanting to regulate or even break up Big Tech — could be avoided through collaboration as web 3.0 is created. Strategic plans should include provisions for interoperability, data portability, and transparency.



INNOVATION

Consumers are spending more time experimenting with or actively using new realities and metaverse technologies. Brands should be a part of the emerging ecosystem, at the very least to learn how consumers behave, interact, shop, discover, and create (content, art, experiences). Beyond gamified experiences, innovation teams should work toward co-creating digital worlds alongside consumers, championing inclusivity and sound ethical practices.



R & D

As digital and physical realities are becoming intertwined, R&D teams in many industries have an opportunity to pursue new moonshots. In 5–10 years, if consumers are wearing heads-up displays in the form of glasses or contacts, how could a retail, QSR/fast casual dining, or fan experience look radically different? How does this impact the patient experience? How might connected eyewear integrate with a car or truck? In what ways could a digital twin be additive to real estate, insurance, and city planning? Developing sound moonshot ideas and the applications to match will enable companies to positively contribute to new realities and the metaverse as emerging platforms are being built.



GROWTH

We anticipate sustained growth for new realities tech and the metaverse ecosystem. This unlocks important opportunities for companies willing to think expansively about alternate futures. For example, virtual possessions—such as a digital fashion—could reduce the number of clothing items consumers buy. While undoubtedly a win for sustainability, digital fashion would be a threat to today's fast fashion brands. If brands develop the processes and business models to support digital fashion, they can expand their market share into new digital environs while mitigating the environmental impact of manufacturing.

Key Questions

We recommend using this report to support your strategic foresight activity in the coming year. Every executive team should begin by asking these questions:

1

- ▶ How can brands ensure that new realities and metaverse spaces are inclusive?

- ▶ How can we close the emerging digital divide in online spaces?

2

- ▶ Will consumers' online personas reflect their real-life ethics and values?

- ▶ In digital spaces, will consumers act as predicted? If not, what impact might that have on our products, platforms, services and strategy?

3

- ▶ As new realities and the metaverse usher in a more decentralized future, will big companies aim to own the platform and experience?

- ▶ If digital identities aren't interoperable across platforms, what problems might that create for our business?

- ▶ In the future, who will be responsible for technical gatekeeping? How does that impact us, our business, our industry, and all of its parts?

Selected Sources

<https://www.descript.com>

<https://www.zdnet.com/article/nixons-grim-moon-disaster-speech-is-a-now-a-warning-about-the-deepfake-future/>

<https://www.zmescience.com/science/news-science/voice-mimicking-ai-dupes-alexa-and-other-voice-recognition-devices/>

<https://breakingdefense.com/2021/10/army-envisions-global-3d-terrain-map-as-future-pnt-aid-for-operations/>

<https://ict.usc.edu/prototypes/one-world-terrain-owt/>

<https://petapixel.com/2021/09/27/speaking-portrait-turns-photos-into-eerily-realistic-talking-heads/>

<https://www.hourone.ai>

<https://www.technologyreview.com/2021/02/12/1018222/deepfake-revenge-porn-coming-ban/>

<https://wolf3d.io>

<https://alethea.ai>

<https://voicebot.ai/2021/10/08/cameo-hires-boss-babys-virtual-clone-and-synthetic-alec-baldwin-voice-to-record-personal-messages/>

<https://www.npr.org/2021/06/17/1007472092/facebook-researchers-say-they-can-detect-deepfakes-and-where-they-came-from>

<https://truepic.com>

<https://jigsaw.google.com/issues/>

<https://www.nextgov.com/emerging-tech/2021/08/senators-introduce-bill-help-agencies-counter-deep-fakes-and-deceptive-media/184227/>

https://www.wipo.int/about-ip/en/artificial_intelligence/policy.html

<https://www.deepword.co>

<https://www.respeecher.com/blog/deepfakes-workplace-synthetic-media-improves-life-office>

<https://www.technologyreview.com/2019/10/10/132667/the-biggest-threat-of-deepfakes-isnt-the-deep-fakes-themselves/>

<https://dot.la/lil-miquela-2655444769.html>

<https://markcubancompanies.com>

<https://www.datacenterdynamics.com/en/news/microsoft-shows-holographic-storage-device/>

<https://about.facebook.com/reality-labs/projectaria/>

<https://www.theguardian.com/technology/2012/jan/24/smartphones-timeline>

<https://markets.businessinsider.com/news/currencies/metaverse-property-sandbox-virtual-real-estate-deal-record-4-million-2021-11>

<https://tech.fb.com/codec-avatars-facebook-reality-labs/>

<https://augmentedforensics.com>

<https://news.artnet.com/art-world/forensic-architecture-interview-1794126>

<https://forensic-architecture.org/about/agency>

<https://www.microsoft.com/en-us/mesh>

<https://research.fb.com/publications/reverse-pass-through-vr/>

<https://www.nreal.ai/light/>



Work, Culture & Play

Tech trends influencing how we will work, what will shape our culture, and how we'll play.



Table of Contents

196	Key Insights	220	Play
197	Work	221	eSports and Gaming
198	Apps Shaping the Remote Workspace	222	eSports Training Academies
199	Accessibility Tech	222	Gaming Subscription Wars
200	Work From Anywhere	222	Infinite Gameplay
202	Home Offices Introduce New Cybersecurity Risks	223	Play-to-Earn Gaming
203	Upskilling	225	Connected Toys
204	Scenario: Hyperlocal Communities	226	Scenario: What to Detect When You're Expecting
205	Next-Gen Gig Economy	227	Digital Addiction
206	Culture	228	Sports Tech
207	The Crypto Art Market	229	Kids Fitness and Educational Games
208	Emerging Art Experiences	230	Protecting Little Gamers
209	IP Rights in the Age of TikTok	231	Application
210	Altered States	232	Key Questions
211	Neuroenhancers	233	Selected Sources
211	Nutrigenomics		
211	Nootropics		
211	Grinder Biohacking		
212	Cannabusiness Tech		
214	Psychedelics		
216	Digital Fashion		
217	Upcycled and Circular Fashion		
218	Scenario: Fashion's Second-Hand News		
219	Digital Beauty		

Key Insights

- * The global pandemic condensed a decade of digital transformation into a few months.
- * Workspace flexibility could bring more women into the workforce, something that would help a shrinking population of workers.
- * A steady tech exodus from Silicon Valley has redistributed a highly skilled workforce to other parts of the U.S.
- * With approximately 2 million people creating content full-time, online creators are redefining entrepreneurship.
- * Newly remote workforces rely on video conferencing systems, messaging platforms, home networks, and home routers that aren't necessarily secure.
- * Smart devices and AI systems are unlocking new ways for athletes to train—and strategic advantages for sports.
- * Gaming has become the driver of an entire cultural and commercial ecosystem.
- * We will see unlikely pairings between gaming competitors in 2022 as Sony and Microsoft acquire studios and PlayStation releases titles on Xbox One and Game Pass.
- * Much of our technology-enabled world leaves behind people with disabilities.
- * Affordable digital clothing, shoes, and accessories will be available this year.
- * AR filters from celebrity makeup artists are taking the place of traditional makeup in video conferences and social media posts.



00

01

02

03

04

05

06

07

08

09

10

11

12

13

Work, Culture & Play

Work

Apps Shaping the Remote Workspace

Interest and investment in remote work platforms increased with the pandemic, and a crop of startups are rising to meet the growing demand. Some provide niche solutions, others offer versatile collaborative platforms, but all have the potential to help shape the future of remote work.

Turing

Companies are using Turing, an artificial intelligence-based platform, to source and vet software developers and manage fully remote engineering teams. Turing also guides its clients in complying with regulations that affect contractors and remote employees. The company has signed over 180,000 developers across 10,000 cities, a pipeline it taps to source teams for client companies. Turing experienced explosive growth during the pandemic and raised \$32 million in Series B funding. As hiring and retaining software developers becomes more difficult, Turing hopes to bridge the gap with its remote team platform.

Remote

Because shifting immigration laws affect companies' ability to tap a global talent pool, startups like Remote are providing

them with an infrastructure to manage onboarding, payroll, and benefits for tech and knowledge workers in remote countries. The company raised a \$150 million Series B round in July 2021 and plans to use the funding to expand into more markets—with a target of 80 countries by the end of 2021—and enhance offerings like visa and immigration support and employee relocation. Remote has an intimate understanding of how to manage a global workforce: Its CEO is based in Amsterdam and its CTO is in Lisbon, Portugal. The company itself is based in New York City with employees working remotely across 47 countries.

Teamflow

Teamflow is a remote work application designed to replicate the organic interactions and conversations of a traditional office environment in a virtual headquarters setting. Users are represented by round icons that display their camera

feeds and move around a virtual-office floor plan to engage colleagues. Users hear only the voices of coworkers whose bubbles are within close proximity, and spatial audio re-creates the directional perspective of an in-person chat. The next generation of the company's software includes a mobile app so that users can access Teamflow from any device, and it will integrate with collaboration tools such as Figma, Trello, and Google Docs.

Gather

This platform aims to create features that promote a sense of spontaneity, such as "shoulder taps" and virtual games of pool, to make virtual interactions feel more natural. The company integrates individual video feeds into a 2D space along with collaboration tools like whiteboards and shared documents. Gather is also working to add deeper customization that helps users re-cre-

ate office spaces and personalize work areas with dogs and seasonal decor. In a Series A round led by Sequoia Capital, the platform raised \$26 million. Work collaboration is the company's focus, but its experience in creating one-time events like Gather bars is likely to position it well for remote team off-sites or internal networking events.

Wonder

Another player attempting to combat Zoom fatigue is virtual networking startup Wonder. The Berlin-based company uses a 2D browser space where users move around as avatars. When you approach another avatar, a video chat opens, making serendipitous virtual chats more the norm than the exception. The map interface allows users to see other groups in the vicinity so that they can move to join those conversations. The company raised \$11 million in a December 2020 seed round.

1ST YEAR ON THE LIST

Accessibility Tech



BlindSquare helps people with visual impairments navigate using audio-based information about their surroundings.

Photo Credit: BlindSquare

KEY INSIGHT

Much of our technology-enabled world leaves behind people with disabilities. The World Health Organization estimates that by 2030, more than 2 billion people will need assistive products, but only 10% will have access to such technology. This field is largely growing through small startups solving very specific problems.

EXAMPLES

Finland-based BlindSquare helps people with visual impairments navigate their surroundings using OpenStreetMap and Foursquare data. The app provides audio-based information about nearby locations such as stores or points of interest and has integrated ride-hailing functionality to create seamless navigation and mobility. Ecuadorian startup Talov offers two accessibility apps. SpeakLiz transforms sound to text and alerts people with hearing impairments about important sounds such as nearby ambulances, motorcycles, or crying babies. The app recently incorporated American Sign Language recognition via the smartphone's camera. Vision was built to translate surroundings for visually impaired people. Using AI, the app verbally describes what it sees through the phone camera or in pictures. It can read text on a menu or street sign or describe an approaching person. Some AI-based tools such as AccessiBe have been criticized for failing to comply with accessibility standards.

DISRUPTIVE IMPACT

Startups have been leading the way in developing accessible technology, though big tech players have started rolling out more accessibility features including sound notifications, sign language recognition, assistive touch, and voice control that uses sounds in lieu of phrases.

While some companies have started using AI-based solutions to assist in making their sites and products more accessible, the algorithms don't appear to be up to the task just yet. Over 600 accessibility experts, including tech-company employees, signed a document requesting that website operators not use automation tools given known reliability issues.

Another issue is funding, especially outside the U.S. For these tools to proliferate, investors will need to reconsider a strategy that has largely ignored this field.

EMERGING PLAYERS

- eSSENTIAL Accessibility
- BlindSquare
- Talov
- AccessiBe
- Evincd

2ND YEAR ON THE LIST

Work From Anywhere



WFA (work from anywhere) equates to a better work-life balance for many, but regulatory challenges and potential mental health issues such as loneliness need to be addressed.

KEY INSIGHT

Significant regulatory changes will be required as more companies adopt permanent WFA policies. As companies evaluate viable long-term options for remote work, potential gains from WFA are significant: a global talent pool, an increase in gender equality, and greater quality of life. But negative effects on society and the individual shouldn't be ignored.

EXAMPLES

Attitudes toward remote work are divided across the board. Companies such as Spotify and Twitter have embraced complete flexibility, including asynchronous working hours. Even the federal Office of Personnel Management's first major policy update in a decade was about enabling teleworking for federal workers. However, most employers demand a partial return to the office. Tax, workers' comp, and payroll regulations require employees to spend the majority of their time at their designated office location. Mandatory office work was a big reason for the "Great Resignation" last year, but at some companies employees have embraced a return to the office in order to better learn from colleagues. And while work-life balance is one of the advertised chief benefits of WFA, the European Union felt the need to introduce a legislative initiative around the right to disconnect so that managers don't badger staff outside of business hours.

DISRUPTIVE IMPACT

WFA opens the door to global opportunities, a significant win especially for employers, as access to top talent, especially in STEM fields, is critical. Workspace flexibility could bring more women into the workforce, something that would help Europe's shrinking population of workers. Carbon-based emissions could be reduced as commutes disappear, but the true environmental effects remain to be seen. Real estate, automobile, and hospitality spending could shift away from the urban core. However, the digital divide could widen in the process: Rural areas need sufficient broadband in order to become destinations for digital nomads, or for existing rural populations to become a part of the global talent pool. What's more, since WFA is a privilege specific to white-collar workers, the remote work movement could further escalate social inequalities.

EMERGING PLAYERS

- CORI (Center on Rural Innovation)
- Horizon Europe
- European Innovation Ecosystems
- Oracle Payroll Core
- Treehouse
- Dandi
- Badi

Art is the elimination of the unnecessary.

— Pablo Picasso

This company will not wait for an uncertain future. We will make our own future.

— Bobby Axelrod in *Billions*

2ND YEAR ON THE LIST

Home Offices Introduce New Cybersecurity Risks



Cyberattacks increasingly target home offices.

KEY INSIGHT

As employees became accustomed to working from their own living spaces in the COVID-19 era, CISOs raised concerns that insecure and unmonitored home networks could expose companies' proprietary data, trade secrets, video conversations, and more to hackers or industry rivals. Working from home is becoming a gateway to new forms of data theft.

EXAMPLES

In 2020, the sudden shift to remote workforces opened wide gaps in cybersecurity for companies around the globe. As we enter year three of the pandemic, cybersecurity threats continue to plague companies. According to a 2021 Deloitte survey, 25% of employees have noticed an increase in fraudulent emails, spam, and phishing attempts in their corporate email since the beginning of the COVID crisis. And a 2021 Tenable study found that 74% of organizations attribute recent cyberattacks to remote work tech vulnerabilities. In a home office setting, threats such as phishing and ransomware can more easily evade corporate defenses.

DISRUPTIVE IMPACT

WFA is our new normal—which means that cyberattacks directed at remote workers will increase. Straightforward ways to mitigate risk and reinforce cybersecurity best practices include requiring two-factor authentication, installing anti-malware software on all machines, increasing privacy settings on home Wi-Fi networks, and even scanning video backdrops for exploitable information. Another option is to invest in cyber liability insurance. Any company that handles highly sensitive or classified materials should consider sending technicians to secure the domestic working environments of all employees with security clearances. Failure to address these vulnerabilities greatly increases the odds of a potentially devastating breach.

EMERGING PLAYERS

- Chubb
- Norton 360
- Malwarebytes
- Wyse

1ST YEAR ON THE LIST

Upskilling



Levi Strauss is building its AI workforce with upskilling initiatives for current employees.

KEY INSIGHT

Investment in upskilling is increasing as both employers and employees look to platforms to help them maintain relevance. Employers are using it as a way to attract and retain talent and meet emerging needs for technology skills and AI capabilities. For workers, upskilling can mean promotions and raises.

EXAMPLES

Levi Strauss is investing in its workforce with an in-house Machine Learning Bootcamp that develops critical AI skill sets in workers with no prior experience. For employers without in-house initiatives, startups are emerging to meet this growing need. Springboard is a mentor-guided platform that has raised over \$50 million and offers several career tracks with guaranteed employment. Palo Alto, California-based Workera.ai conducts regular technical skills assessments and creates personalized learning plans to help employees meet employer-required skills and their career goals. This “precision upskilling” helps to close skills gaps and develop teams, according to the company. India-based Apna aims to help blue- and gray-collar workers learn new skills. The company was valued at \$1.1 billion after a \$100 million Series C round in September 2021. These platforms position upskilling as an opportunity for employees to grow their promotion and earning potential while reducing turnover.

DISRUPTIVE IMPACT

Companies such as Levi's, Target, and Walmart are using upskilling platforms to retain and retrain employees. Quick-service restaurant chain Chipotle found that employees who participated in its program with Guild were 7.5 times more likely to move into a management role. There are also initial examples of how upskilling programs may support diversity, equity, and inclusion goals. As technology accelerates, employers will need an increasingly agile workforce that can adapt its skill sets and capabilities. Expect to see increased investment in upskilling platforms to help them meet those needs.

EMERGING PLAYERS

- Guild Education
- Section4
- Workera.ai
- Springboard
- NewCampus
- OpenClassrooms
- Unacademy
- Emeritus

Hyperlocal Communities

A rapidly mutating environment has reshaped the world: Rising sea levels crept inland, acidification and plastic waste choked the oceans, and heat waves and fires wiped out biotas and razed rainforests. The destruction redistributed the human population across the remaining habitable landmass. As a result, research scientists, technologists, and urban planners created a new model for living: hyperlocal communities.

Designed to meet the demands and limitations of the new environment, these self-contained communities are entirely self-sufficient. Every need is drawn locally—vertical farms grow crops, biofoundries synthesize medicine, and 3D printers churn out construction materials, clothing, and other goods. There is no reliance on outside supply chains, and travel is naturally limited because of the dangers posed by the climate.

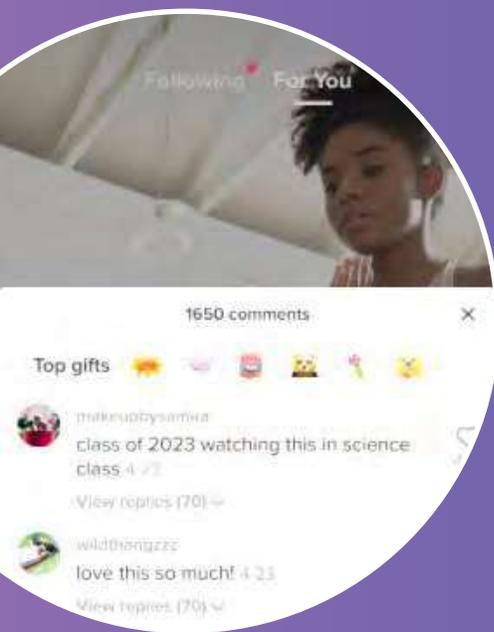
Consequently, these communities self-isolate and define themselves around specific value systems. One community operates within a capitalist structure with a focus on health, human longevity, and animal welfare, with strictly vegan sources of nutrition. Another rallies around aesthetics, including refined architecture and plastic surgery—molded faces and bodies dictate a person's socioeconomic class. Yet another community leans into socialist ethos and relies on ubiquitous tracking and algorithmic analysis to manage the egalitarian distribution of wealth and resources.

While cities of the past may have embraced multiple societal layers where disparate demographics intermingled, these settlements offer unique experiments in intentional living—and if successful, they could offer a sustainable model for future communities.



1ST YEAR ON THE LIST

Next-Gen Gig Economy



Platforms such as TikTok are launching new ways for creators to earn money from content.

Photo Credit: TikTok

KEY INSIGHT

With approximately 2 million people creating content full-time, online creators are redefining entrepreneurship. While platforms compete over top creators, the talent is beginning to shift away from reliance on brands and platforms and more toward direct-to-consumer models. An ecosystem of as-a-Service startups is emerging to support this next-gen gig economy.

EXAMPLES

TikTok sparked a competition for creators in 2020 with its \$2 billion fund. Snapchat quickly followed with \$130 million in Spotlight payments, while YouTube pledged \$100 million to back Shorts. Platforms also lured creators with monetization features like subscriptions, tipping and marketplaces for paid partnerships. Venture capitalists are taking notice of the growing ecosystem of creator-focused startups, and investing an estimated \$2 billion. Pietra connects creators with the design, manufacturing, and logistics partners they'll need to launch their own products. When creators want to expand, Jellysmack helps them redistribute content to other platforms. Financial startup Karat extends credit based on metrics such as follower count and engagement rather than FICO scores. Creator-backed funds such as Creative Juice's Juice Funds mirror VC funding structures. And crypto startup Pools develops personalized tokens that allow creators to sell exclusive access and content.

DISRUPTIVE IMPACT

Global consumer spending in social apps is estimated to reach \$6.78 billion in 2021, driven in part by user-created video and live streaming. The creator economy isn't new, but it is accelerating, and platforms are investing in creator funds and features to lure influencers away from competitors.

This economy mirrors many of the wealth inequities of the overall economy. Only 10% of Twitch's 3 million streamers have gained the Partner or Affiliate status needed to earn income. On YouTube, creators may make \$3 to \$5 per 1,000 views. At the same time, platforms are charging fees that shrink that revenue by as much as half.

Power in the industry is starting to shift, however, with new startups and decentralized collective actions like the #DayOffTwitch protest in September 2021. Expect to see the industry continue to morph as creators expand into new markets and revenue models.

EMERGING PLAYERS

- Pietra
- Jellysmack
- Karat
- Pools
- Creative Juice
- FYPM
- Pearpop
- Streamloots



Consumers spent an estimated 548 billion hours live streaming in top social apps in 2021.

— "The Evolution of Social Media Apps," a report from App Annie



- 00
- 01
- 02
- 03
- 04
- 05
- 06
- 07
- 08
- 09
- 10
- 11
- 12
- 13

Work, Culture & Play

Culture

1ST YEAR ON THE LIST

The Crypto Art Market



Only time will tell whether crypto art can evolve from a novelty and speculative investment into an innovative, critically acclaimed medium.

KEY INSIGHT

As individuals begin to see greater value in virtual items, new technologies are redefining the digital experience of creating, authenticating, acquiring, owning, and investing in art. From NFTs to works generated by artificial intelligence, innovation is shaping the way virtual art will function and be consumed, particularly in the metaverse.

EXAMPLES

During early crypto-mania, there was a common cautionary refrain: The latest coin or currency isn't necessarily the innovation, blockchain technology is the innovation. The art world has recently experienced a similar tech-inspired craze, with the introduction of non fungible tokens, or NFTs, digital works that offer unique, secure proof of ownership despite being easily replicable. As metaverse environments take shape, the value and function of blockchain-backed artwork will evolve. A user can purchase these digital works in marketplaces such as OpenSea, SuperRare, and Nifty Gateway; display it in a virtual environment; and welcome others to engage with the piece, by scanning it to verify its authenticity, determine whether it was created by a human or an algorithm, or trigger an animation or immersive experience. The work may even contain a digital signature that can be written into the code of a user's avatar, making it a living record of their digital art spectatorship.

DISRUPTIVE IMPACT

The NFT art craze has minted a new class of blue-chip artists whose graphic style lends itself to the format, but purists in the art world see much of that work as an overhyped techno-gimmick. Regardless of any one artist's merits, it is clear that blockchain technology is shaping the market for virtual art, enabling the tracking of works, the verification of their provenance, and protection from counterfeiting, while allowing creators (both human and AI) to receive royalties from successive sales of a work. In many current marketplaces for blockchain-backed digital works, art overlaps with collectibles, ephemera, virtual fashion, digital pets, avatars, and more. As the novelty of NFTs wears off, expect more differentiation in the market when more artists find creative applications of these new technologies to add value to their works, eventually convincing even traditionalists and critics to acknowledge the legitimacy of virtual art.

EMERGING PLAYERS

- Axie Marketplace
- Blockchain Art Collective
- Ethereum
- Institut
- Nifty Gateway
- OpenSea
- Rarible
- SuperRare

1ST YEAR ON THE LIST

Emerging Art Experiences



Meow Wolf Denver houses a large-scale physical fabrication of The Cathedral[that the company digitized for The Infinite Playa, a recognized universe in the Burning Man's multiverse.

Creative commons

KEY INSIGHT

Emerging forms of experiential and virtual art illustrate the formats and technologies that will influence the art world's adaptation to the metaverse.

EXAMPLES

With new technologies at our disposal, and a growing cultural interest in experiences that traverse virtual and physical aspects of the nascent metaverse, the art world is abuzz with innovation. Entirely virtual museums have cropped up, like the Virtual Online Museum of Art, and nonhuman creators have come on the scene, such as Ai-Da, an AI-powered humanoid robot artist who has performed at Abu Dhabi Art and the Barbican Center in London. New endeavors like Superblue, backed by mega-gallery Pace and Laurene Powell Jobs' Emerson Collective, seek to curate shows that eschew the art object in favor of the art experience, breaking down borders between artist, art, and observer, and spanning virtual and physical formats.

DISRUPTIVE IMPACT

In the late 2010s, the viral popularity of works such as artist Yayoi Kusama's "Infinity Mirrors" sparked a debate. Was such work, which immersed visitors in a physical environment with dazzling optical effects—and owed much of its popularity to its "Instagrammability"—genuine art? Or was it just a social media content farm, with ticket holders as its paying customers? Could it be both? These pieces gave an early glimpse of how blending digital and physical experiences and blurred lines of authorship will stretch the definition of art as it evolves in virtually enhanced spaces. As with many aspects of the metaverse, virtual art experiences will reach a new level of immersion and interactivity once advanced smart glasses hit the consumer market, and blockchain applications will enable new ways for audiences to engage with the artwork and log their art experiences.

EMERGING PLAYERS

- Ai-Da
- Artechouse
- Fotografiska
- Google Arts & Culture
- Kunstmatrix
- Meow Wolf
- Superblue
- TeamLab
- Virtual Online Museum of Art

1ST YEAR ON THE LIST

IP Rights in the Age of TikTok



If your signature moves get copied by a dancing banana avatar in “Fortnite,” can you sue?

Epic Games

KEY INSIGHT

Intellectual property is immaterial by nature, which makes social media and virtual environments in the metaverse breeding grounds for new forms of IP, giving rise to complex legal challenges in protecting the rights and ownership of its creators.

EXAMPLES

Among the resources listed on law services site LegalZoom, one offering seems particularly relevant to the TikTok era: “How to Copyright a Dance.” In 2018, when rapper 2 Milly heard that avatars in “Fortnite” could unlock his “Milly Rock” dance as an in-game feature, he filed suit against the game’s developer, Epic Games, but ultimately dropped the suit because he had not copyrighted his moves. This high-profile case raised an important question: With new platforms and digital interfaces continuously emerging, should creators be taking more precautions to protect their work online? Virtual IP challenges are not limited to dance moves, of course. Media lawyer Sophie Goossens notes that NFTs, the suddenly popular new form of digital art ownership, can function well as property titles and stores of information on the artwork—but non fungible tokens don’t necessarily assign ownership of the IP it may contain. IBM, meanwhile, is developing what would be the first patent NFT exchange designed for IP.

DISRUPTIVE IMPACT

Upon the appointment of new CEO Parag Agrawal in November 2021, Twitter promptly announced it was restricting users from posting images or video of someone without consent, with an updated privacy policy that allows individuals to reach out to the platform to have content of themselves removed. When your likeness is accessible on the internet, it can be memed and monetized without your knowledge or approval, and without you receiving any value from the content’s virality. Whether it’s a gaming platform or social account profiting off your dance moves, an NFT owner monetizing your art, or an ad agency deepfaking your face and voice to sell products, intellectual property rights are about to get a lot more personal, and affect a far greater swath of the general public.

EMERGING PLAYERS

- Reed Smith
- True Return Systems
- IBM
- IPwe

4TH YEAR ON THE LIST

Altered States



KEY INSIGHT

From “nootropics” to neuroenhancers, the consumer market for altering our mental state is growing. Products are emerging to help you achieve everything from escape to enhancement.

Doppel uses vibrating rhythms on the inside of a user's wrist to reduce stress and increase focus.
Epic Games

Credit: Doppel

EXAMPLES

Consumers are seeking altered states, from high-tech enhancement to synthetic escapes. These products are designed to strengthen our mental performance and agility, help us disconnect and relax, and give us pleasure. Despite thin evidence supporting the claimed benefits, personal experimentation is booming.

DISRUPTIVE IMPACT

In a March 2021 survey by employment website Indeed, 52% of respondents reported feeling burned out. More than two-thirds believed their burnout worsened during the pandemic. People are struggling to navigate this uncertain terrain, so it's no surprise that more of us are seeking artificial ways to temporarily change our moods and optimize ourselves.

EMERGING PLAYERS

- Walletmor
- Muse
- Sens.ai
- Kin Euphorics

Altered States

■ Neuroenhancers

Neuroenhancement devices claim to make you more productive or boost your mood. Most rely on tracking brain waves through electroencephalography (EEG). SmartCap assesses real-time fatigue levels through an EEG band. The wearable device alerts users when they are at risk of falling asleep. SmartCap Technologies' assets and intellectual property were acquired by Wenco International Mining in May 2021 to augment its worker safety portfolio. The Muse headband uses real-time biofeedback to help people maintain focus during the day and support recovery at night. What to do with that improved focus? A YouTuber named Cangar modified the Skyrim VR game for use with the headset so that when a wearer increases their focus, their magic in the game becomes more powerful. The second-generation headband released in 2021 added a Digital Sleeping Pill feature that delivers

content to help a user go to sleep and stay asleep longer. Canadian neurotech startup Sens.ai launched its brain-training headset and platform as an Indiegogo campaign. By early December 2021, the campaign had raised over \$650,000. The company claims the device optimizes brain performance using EEG neurofeedback, infrared light therapy, and heart-rate variability training. Doppel sends vibrations through a wrist-worn device, with rhythms that can be personalized to help you feel relaxed, calm, focused, alert, or energized.

■ Nutrigenomics

As genetic testing becomes widely accessible and affordable, startups are claiming that genomic sequencing can determine how to personalize nutrition to optimize weight loss, immune function, and personal health. Nutrigenomics studies the effects of food on gene expression and how specific

nutrients or diets affect human health. All nutritional decisions—what foods to avoid, what supplements to take—are based on your personal baseline sequence. The market is small, with a dozen companies offering this analysis. The service is particularly attractive to consumers battling chronic illness and athletes looking for a competitive edge. The scientific community is split on the benefits of nutrigenomic testing given limited clinical evidence.

■ Nootropics

“Nootropics” are designed to boost brain performance. Often called cognitive or memory enhancers, they have caffeine-like stimulative effects. Beverage companies have responded to increasing demand with a flood of new functional beverages that use nootropics and adaptogens instead of alcohol. Many functional beverages on the market today leverage naturally oc-

curing components that claim to offer bursts of calm, euphoria, or creativity. Kin Euphorics features L-theanine, an amino acid found naturally in tea and mushrooms said to modulate brain function and induce relaxation without drowsiness. Supplement startup Formula uses a proprietary algorithm to customize nootropics to a user's personal lifestyle and goals.

■ Grinder Biohacking

For years grinder biohackers have self-experimented with implanted devices including RFID tags, NFC chips, data storage, and biosensors. That same mindset sparked startup Walletmor to launch a biopolymer contactless payment implant in June 2021. Other grinders play with oxygen deprivation, microdosing, or use of injections to optimize and gain function. LMS Wellness is a clinic with locations across the globe that specializes in “scientifically backed”

biohacking with offerings designed to spark regeneration from your metabolism to your skin.

1ST YEAR ON THE LIST

Cannabusiness Tech



Cannabis companies are turning to biotechnology and plant genetics to optimize strains for yield and drug profiles.

KEY INSIGHT

The global cannabis market is expected to reach \$70.6 billion by 2028, according to Grand View Research. Despite its heft, U.S. cannabis business owners often struggle to manage operations due to federal regulations that largely view their businesses as illegal; however, technology is emerging to support retailers and consumers.

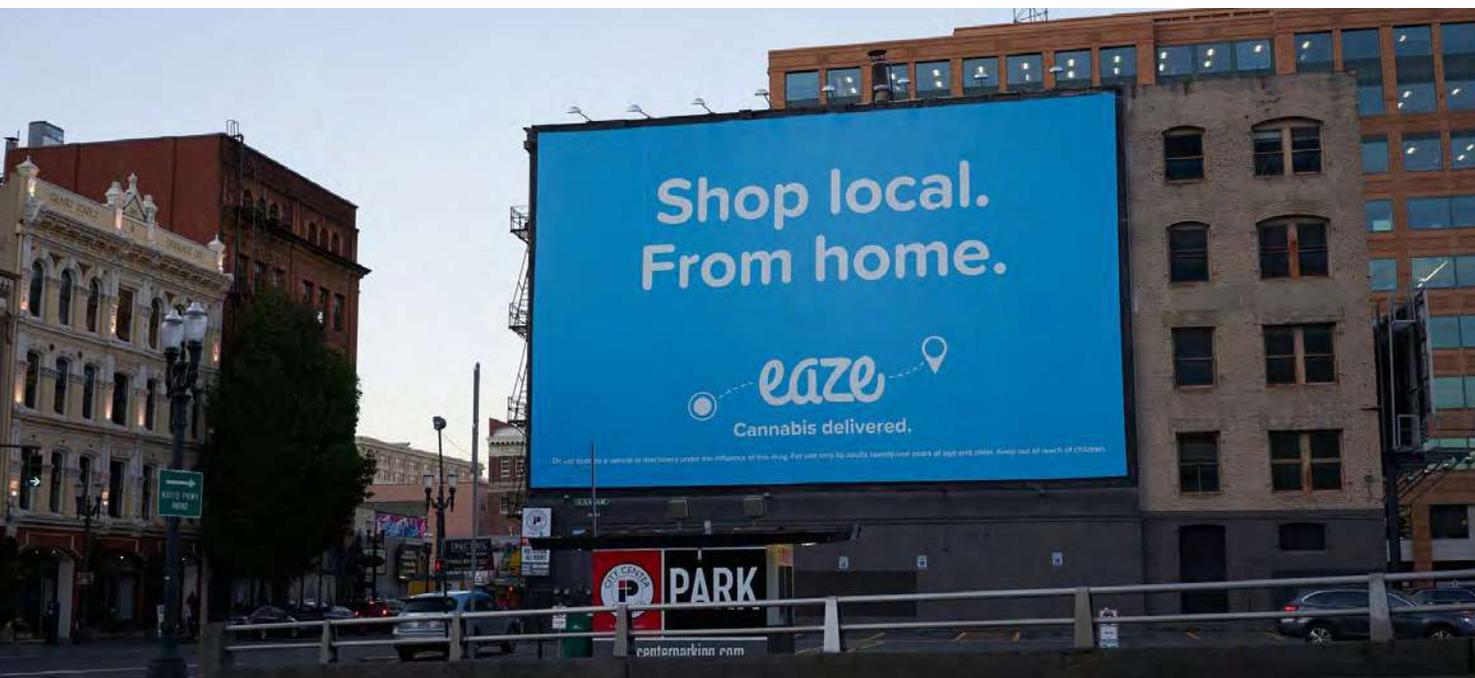
EXAMPLES

Endocanna Health's at-home DNA tests recommend ideal cannabis strains and dosages. Israeli RCK optimizes plant genetics for private label strains. Dewey Scientific leveraged its genetics work to raise \$3.2 million from The Hawthorne Collective, the cannabis investment arm of Scotts Miracle-Gro, FolioGrow, Front Range Biosciences, and agtech iUNU use AI-based prediction models and fully automated grow operations to optimize THC/CBD ratios, yield, and profitability.

Apple loosened App Store restrictions in July 2021 and opened the door for Weedmaps and Uber Eats to offer in-app ordering. Meadow's Dynamic Delivery streamlines delivery by providing real-time inventory of nearby vehicles. Digital identity startup Passbase offers software development kits for remote customer identity verification, and A.ID automates due diligence like checking watch lists and reporting suspicious activities.

Digital payments are easing this industry's cash-intensive nature. KindTap and SuperNet offer innovative consumer credit products that skirt restrictions. AeroPay enabled online payments through e-commerce platform Jane Technologies' multistate marketplace.

Cannabusiness Tech



Delivery service Eaze acquired retailer Green Dragon in 2021, becoming the largest American cannabis delivery service.

DISRUPTIVE IMPACT

Insurance and banking continue to be problematic for an industry that is legalized state by state. At the federal level, the Secure and Fair Enforcement (SAFE) Banking Act and related Clarifying Law Around Insurance of Marijuana (CLAIM) Act, which were reintroduced by Congress in March 2021, would prohibit federal regulators from penalizing financial institutions and insurance providers that serve legally operating cannabis-related businesses. Legalization issues haven't slowed investment in the industry, however. As the industry continues to professionalize, we will see the ecosystem continue to build up around a product that is emerging from the shadows and becoming just another line of business.

EMERGING PLAYERS

- Endocanna Health
- Strain Genie
- The Hawthorne Collective
- The Secure and Fair Enforcement (SAFE) Banking Act and Clarifying Law Around Insurance of Marijuana (CLAIM) Act
- SuperNet
- Front Range Biosciences
- Fire & Flower
- Meadow

1ST YEAR ON THE LIST

Psychedelics



Field Trip Health offers psychedelically enhanced psychotherapy in a resort-like environment.

Credit: Field Trip Health

KEY INSIGHT

Psychedelics are a small but fast-growing market with some estimates valuing it at \$7 billion by 2027. Despite the clinical trials, Food and Drug Administration approvals, and breakthrough therapy designations, the field straddles a gray space between accepted medical treatment and recreational drugs. Shifting regulations and increased investment may help it bridge those worlds.

EXAMPLES

The field is gaining credibility as respected institutions open specialized research centers and larger studies reinforce the potential of psychedelics in treatment of PTSD, major depressive disorders, and addiction. In September 2021, the National Institutes of Health awarded Johns Hopkins Medicine \$4 million to investigate the effectiveness of psilocybin in smoking cessation—the first time in 50 years that the U.S. government has funded psychedelic research. The following month, the FDA gave biotech Cybin clearance to study brain activity during psychedelic experiences using Kernel Flow neuroimaging. Consumer services are also expanding. Entheon Biomedical offers a genetic test to predict individual response to psychedelics. Canadian startup Field Trip Health has clinics in six major U.S. cities that offer ketamine therapy sessions in a setting that resembles more of a wellness resort than a medical facility.

DISRUPTIVE IMPACT

Industry tracker Psilocybin Alpha reported 32 publicly traded companies working in psychedelics and at least 18 more privately held. STAT reported that the industry had grown quickly from a market cap of less than \$1 billion in 2020 to having four billion-dollar companies in 2021. With the amount of investment in the area, it's not surprising to see an ongoing battle around patents that may restrict research into certain psychedelic compounds and limit treatment approvals to synthetic versions only.

Regulations are changing. Oregon became the first state to legalize psilocybin therapies in November 2020 while D.C., Detroit, Denver, Oakland, and Santa Cruz decriminalized psilocybin. In Canada, all 13 provinces and territories have exemptions for psychedelic mental health treatment. British Columbia, which has fully embraced the cannabis industry, is home to many psychedelic startups. In Australia, the federal government invested \$15 million to support research into psychedelics and mental health.

EMERGING PLAYERS

- MindMed
- Cybin
- Field Trip Health
- Compass Pathways
- Atai Life Sciences
- Entheon Biomedical
- Centre for Psychedelic Research at Imperial College London
- Center for Psychedelic and Consciousness Research at Johns Hopkins Medicine
- New York University Langone Center for Psychedelic Medicine

“
**Fashion is very important. It is life-
enhancing and, like everything that gives
pleasure, it is worth doing well.**

— Vivienne Westwood

”

2ND YEAR ON THE LIST

Digital Fashion



Virtual wardrobes will allow users to customize and organize digital garments for use in augmented reality environments, and to track and manage their physical clothing.

KEY INSIGHT

Digital fashion is booming, with the market for gaming avatar skins alone expected to hit \$50 billion in 2022. Virtual apparel is expected to give rise to digital wardrobes, generate valuable user data, and provide a potential—though not guaranteed—sustainability solution for the notoriously pollutive fashion industry.

EXAMPLES

In 2021, Dolce & Gabbana launched a collection of fashion NFTs alongside physical garments, which together sold for a record-breaking \$5.7 million worth of Ether cryptocurrency. One of the purchasers was Red DAO, a collective investment entity focused exclusively on digital fashion. Non fungible token technology allows for digital fashion like D&G's virtual pieces to be collected, but individual users may only be able to clothe an individual avatar in virtual digital garments in a single online platform or gaming environment, limiting use across various multiple digital spaces in the metaverse. Startup Digitalax is tackling that issue, developing an interoperable platform for digital fashion. High fashion houses from Gucci to Louis Vuitton have partnered with gaming platforms including Roblox and League of Legends, and online fast fashion retailers such as Shein are gamifying the apparel retail experience, a concept that could be well suited to digital fashion.

DISRUPTIVE IMPACT

Physical garments may soon come with virtual counterparts, allowing users to catalog and manage their wardrobes digitally, and hang on to a version of a garment even after the physical piece degrades. The ability to express oneself freely in the metaverse through virtual styles may encourage more sustainable shopping habits when it comes to physical apparel. In time, as smart glasses become commonplace, users may even be able to virtually showcase their digital looks on their bodies instead of just on an avatar. Imagine a future in which you select a simple sustainable garment or “canvas” from your physical closet, but select a virtual outfit to project on top of it, one that is visible to anyone wearing compatible smart glasses. Digital fashion houses like The Fabricant, Replicant, and RTFKT are looking to satisfy growing demand for unique, dynamic virtual looks, which will eventually be de rigueur in social, gaming, and work environments in the metaverse.

EMERGING PLAYERS

- Auroboros
- Carlings
- Dapper Labs
- Digitalax
- Dolce & Gabbana
- DressX
- The Dematerialised
- The Fabricant
- Gucci
- Happy99
- Red DAO
- Replicant
- RTFKT
- Tribute
- UNXD

2ND YEAR ON THE LIST

Upcycled and Circular Fashion



Textile factories built for high-volume production have contributed to massive overproduction in fashion; in the past 25 years, the average amount of clothing Americans throw away annually has more than doubled.

KEY INSIGHT

Tens of billions of clothing items are produced each year, much of it designed for short-term use and ultimately destined for landfills. Apparel manufacturers are exploring new methods to prolong the life of their goods, repurpose used materials, and reduce the climate impact of product life cycles.

EXAMPLES

According to analytics firm First Insight, more than half of Gen Z customers surveyed prefer to buy from sustainable brands, and big name retailers have taken note. The Gucci-Up initiative is an effort from the Italian fashion house to pilot circular production models by upcycling leather, eliminating the use of virgin plastics, and generating materials from industrial waste. H&M's Looop program disassembles old textiles to create new products without using virgin materials. Companies such as ThredUp and The RealReal have established reliable second-hand apparel marketplaces to extend the life of existing fashion products. On the manufacturing side, fiber-to-garment textile parks, like those built in India over the past decade, can reduce emissions by localizing supply chain segments.

DISRUPTIVE IMPACT

Sustainability is the single greatest challenge facing the fashion industry—and also its greatest opportunity. An investment in circular production models now may pay dividends as the purchasing behaviors of the next generation of conscientious consumers matures and shapes the industry. Digital fashion is set to play a significant role in the sustainable transformation of apparel brands, not just by providing a new revenue stream to balance lower-volume production of physical garments but also by revealing previously inaccessible post-purchase data. Virtual garments could eventually serve as digital twins to track physical garments via a digital wardrobe interface, logging usage, treatment, and end-of-life trends, and generating insights to inform new approaches to circularity. Additionally, synthetic biology could be used to develop fibers that are less resource-intensive, make for longer-lasting materials, and are more easily broken down or recycled.

EMERGING PLAYERS

- ASOS
- British Fashion Council's Institute of Positive Fashion
- Ellen MacArthur Foundation
- H&M Looop
- Marine Serre
- MUD Jeans
- Napapijri
- Patagonia
- Platform for Accelerating the Circular Economy
- The RealReal
- Reformation
- ThredUp

Fashion's Second-Hand News

Driven by early 21st century concerns of environmental waste and climate change, multinational apparel brands explored sustainable alternatives—and found them by tapping an existing network of thrift stores.

Goodwill and the Salvation Army became inspired by popular resellers like Grailed, The RealReal, and Depop, and began recruiting teams of “pickers” to sift through donations for gems—quality denim, vintage finds, or brand names. They set them aside for bigger sales. Soon, large apparel brands turned to these charitable organizations and consignment stores to be suppliers of pre-owned

garments and upcyclable materials and support new sustainable business models.

Today, the primary and resale clothing markets have merged into a circular “throughsale” market, and repurposed garments and materials drive the majority of apparel sales—even at big brands. Second-hand shops generate steady revenue, apparel makers maintain healthy margins while reinventing themselves, and the fashion industry's former reputation as a major polluter is now considered, well, vintage.

3RD YEAR ON THE LIST

Digital Beauty



AR beauty filters can be used to virtually test makeup products, or to alter one's appearance in recorded content and live video interactions.

KEY INSIGHT

Digital makeup exists at the intersection of facial recognition, 3D mapping, and augmented reality. As the metaverse becomes a part of our everyday lives, digital touch-ups and expressive virtual makeup will define how we choose to present ourselves to the world—and how we see ourselves.

EXAMPLES

If you've been on Zoom calls recently, chances are you've seen a digital beauty filter in action. The adjustable feature, billed by Zoom simply as "Touch Up My Appearance," smooths imperfections in the user's face and seamlessly animates along with their movements in real time, essentially acting as virtual makeup. Digital beauty is the addition of virtual embellishment to one's face or body in photo or video content, through the use of augmented reality and artificial intelligence. The effect can range from subtle aesthetic touch-ups to flamboyant makeovers to transformation of a person's facial features and figure. Beauty brands including Redken, Avon, MAC Cosmetics, and Maybelline have picked up on the trend, offering AR filters for users to virtually try on beauty products via live video. L'Oreal, meanwhile, has created a line of digital-only beauty products to be used in popular social and videoconferencing apps.

DISRUPTIVE IMPACT

Digital beauty filters are easily accessible through many social media platforms, some video interfaces, and third-party apps like Facetune. More than just an expressive virtual accessory, an aesthetic filter can have a direct effect on business. Imagine digital mirrors that artificially accentuate shoppers' features at a retail shop, subtly encouraging them to purchase a piece of clothing. Users of Alipay's facial scanning payment feature complained about their on-camera appearance, prompting the company to add a digital beauty filter to improve the experience. As smart glasses enable the application of beauty filters during in-person interactions, and advanced video interfaces allow users to appear as live, virtually beautified versions of themselves, the full spectrum of digital beauty technology's effects must be considered. While filters can build confidence and boost business, they can also trigger dysmorphia by exposing audiences to unrealistic beauty standards.

EMERGING PLAYERS

- Adobe Lightroom
- AliPay
- Drest
- Essence Cosmetics' Kenna
- Evenprime
- FaceApp
- Facetune
- Florasis
- Ines Alpha
- L'Oreal
- Revieve
- Spellbreak
- Zepeto



00

01

02

03

04

05

06

07

08

09

10

11

12

13

Work, Culture & Play

Play

4TH YEAR ON THE LIST

eSports and Gaming



Gaming has not only legitimized itself but has become the driver of an entire cultural and commercial ecosystem.

KEY INSIGHT

The video game industry has emancipated itself from other entertainment verticals to become the driver of a whole ecosystem of cross-platform franchises and experiences. It's managed to firmly position itself in the mainstream of Asian, North American, and European youth culture. ESports are benefiting through exponential growth in viewership and commercial investments.

EXAMPLES

Netflix has renewed its "Arcane" series, based on Riot Games' "League of Legends." Balenciaga designed skins in "Fortnite." Splash's virtual pop star Kai gained more than 1.9 million YouTube views for the music video "Breathe Again." 100 Thieves co-owner Valkyrae launched her own skin care line aimed at gamers, and eSports organization FaZe Clan teamed up with crypto payments company MoonPay to ease crypto access for its users and sell NFTs. Aiming to blend celebrities from eSports and other professions, the Complexity Stars initiative cross-pollinates audiences through tournaments and other brand-amplifying strategies. In Asia, eSports will make their official debut at the 2022 Asian Games, the second largest multisport event in the world, after the Olympic Games. And Dubit created the Metaverse Gaming League, the first live eSports league in the metaverse.

DISRUPTIVE IMPACT

Traditional sports tournaments returned last year, but eSports continued to rise in popularity. The U.S. deregulated eSports betting in some states, catching up to Europe, where the practice is legal in many countries. Twitch held its place as the most popular streaming platform, with 66% of all hours watched. However, Facebook Gaming, which captured merely 11% of audience time, has begun to introduce features that make the viewing experience more interactive, setting the stage for a potential increase in popularity.

While sponsorship money and other traditional forms of monetization have skyrocketed, Halo Infinite League introduced a new revenue model: Teams license their brands for in-game cosmetics and get a percentage of the revenue. Mobile gaming, the fastest-growing segment in the gaming industry, already has a thriving eSports scene in China, which could foretell a similar development in other regions. How the country's three-hour weekly gaming limit for minors will impact its eSports remains to be seen.

EMERGING PLAYERS

- Dubit
- Complexity
- Splash
- Balenciaga
- FaZe Clan
- Halo Infinite
- Facebook Gaming



People want to lean back and be told good stories. And the other part is interactive play, which grows into video gaming.

— Reed Hastings,
Netflix CEO

eSports & Gaming



T1 Esports Academy offers two paths—one for those seeking to become professionals and one for recreational players.

Credit: T1 Entertainment & Sports

■ eSports Training Academies

More than 175 colleges and universities have started varsity eSports programs, and eSports training academies are proliferating across the globe. In India, gaming hardware manufacturer ASUS Republic of Gamers announced its own academy in January 2021. ESports organization T1 announced an academy in Seoul, South Korea, that offers two paths: one for aspiring professional gamers and one for recreational players. Edge Gaming in Israel plans to use a \$2 million pre-seed round to develop its own dedicated eSports academy with an approach based on military training around cognitive skills and split-second decision-making. If it seems like everyone is launching an academy, you might be right. Soccer club Paris Saint-Germain announced it was entering the field in December 2020. U.K.-based GuildAcademy for eSports has programs for children starting at 11 years old. The program seeks to offset concerns about

offering such an early start with wellness features like peer-to-peer coaching, parental settings, and a curriculum covering mental health issues, nutrition, and social skills. Microsoft has even created an Esports Teacher Academy to teach instructors how to build an eSports program at their own schools.

■ Gaming Subscription Wars

Subscription models for gaming began to emerge in 2017. Since then, models have proliferated, and Morning Consult reports that half of all gamers now subscribe to at least one subscription service. Microsoft's Xbox Game Pass has become so important to the business that subscriber growth is reported on investor calls. Of the 30 games that Microsoft announced in October 2021, 27 were included with the subscription service, with the company positioning it as, "Play it day one with Game Pass." Sony is expecting to launch its subscription service in spring 2022. It will merge

the existing PlayStation Plus and PlayStation Now plans and offer both new and classic games for PlayStation 4 and PlayStation 5. The past year also saw a new entrant in subscription gaming: Netflix. The streaming giant accelerated its gaming efforts in November 2021 by adding three games to its lineup and hiring Amir Rahimi from interactive entertainment company Scopely as its vice president of game studios. The industry is paying close attention to the company's investments and moves in the gaming space.

■ Infinite Gameplay

The most popular video games today have something in common with the metaverse: persistence. In other words, they never end. Rather than traditional games with a conclusive narrative, many of these games are more like online worlds, where players participate whenever and for however long they like, with success measured in achievements

eSports & Gaming



Guild Academy offers training programs for kids as young as 11 years old but has built in wellness features to offset the perceived lifestyle risks of gaming.

Credit: Guild Academy

instead of the completion of a single, finite objective. In these always-on gaming environments, players can also take part in hybrid real-world experiences like going to a concert or buying real estate. “The Sims” and “Minecraft” are examples of longstanding games that allow players to build their own realities, while more recent titles such as “Fortnite” and “League of Legends” are immersive universes that players can log in to at any time. Moving forward, our lives will be increasingly gamified, as never-ending games merge with the activities that already form parts of our daily lives.

■ Play-to-Earn Gaming

When the pandemic drove populations across the world indoors, many turned to video games to pass the time, while others took up gaming for more practical reasons—to supplement their incomes. “Axie Infinity,” a Vietnamese-made online game that features NFT

characters and awards players tokens that can be traded on the Ethereum blockchain, exploded in popularity, particularly in the Philippines and Venezuela, which together home about half of the game’s millions of users as of 2021. “Axie” and many other online play-to-earn games, including “The Sandbox,” “Splinterlands,” “Virtue Poker,” “Sorare,” and those in the Decentraland platform, rely on NFTs and blockchain tech, and can provide a moderate source of income for users, transforming the nature and function of gameplay. This emerging field of games, sometimes described as GameFi (a play on DeFi, or decentralized finance), can see many millions of dollars in value exchanged daily via in-game assets. The space is increasingly seen as the future of gaming in the metaverse, leading to a spate of venture investment—in 2021, “Axie’s” parent company, Sky Mavis, raised \$152 million in Series B funds at a valuation of \$3 billion.



Sony plans to launch an Xbox Game Pass competitor in spring 2022.



The last two years in particular have shown how critical games are to helping people maintain a sense of community and belonging, even when they are apart.

— Satya Nadella, CEO, Microsoft



3RD YEAR ON THE LIST

Connected Toys



AI-enabled smart toys can be cute and engaging, but don't let your guard down—they may give companies and hackers access to sensitive data.

KEY INSIGHT

Connected toys share and receive data to personalize and optimize interactive experiences. While the toys are fun and potentially beneficial for kids, lawmakers and academic researchers have raised questions about cybersecurity and privacy.

EXAMPLES

The promise of connected toys is appealing—imagine a toy that can interact with your children, keeping them more socially engaged, responding to their real-time emotional state, telling them to take a break if they've been playing for an extended period, or even notifying you if your children are in distress. But that same toy could also be capturing data about your children and your home, and a current lack of regulation in the industry means that sensitive data could be shared with the device maker, or be vulnerable to hackers. Toys like Sony's Aibo interactive robotic dog, first introduced in 1999, are now equipped with computer vision technology to recognize their owners, and "Mario Kart Live: Home Circuit" incorporates mixed-reality technology to allow players to drive camera-equipped remote-control cars around their own homes. Additional STEM-related educational smart toys include Artie 3000, a programmable robot that likes to draw, and Sphero, a robotic ball with interactive coding games.

DISRUPTIVE IMPACT

Think about connected toys as not just toys but devices. Just as users are wary of devices such as smart TVs and speakers "spying" on them, parents should be discerning with connected toys if they want to reap the benefits without sacrificing security or privacy. The upcoming generation of connected toys will use more data and include even more personalization, and advancements in computer vision, voice and sound recognition, and spatial computing will result in richer, more interactive experiences. As connected toys evolve, they will rely less on mobile devices and instead connect to the cloud. With an expected growth rate of 28% over the next four years, the smart toys market is due for rapid expansion—but tech companies and toy manufacturers are still learning how to balance children's privacy, which is required under the Children's Online Privacy Protection Act (COPPA), with play.

EMERGING PLAYERS

- AWS
- Bandai Namco Holdings
- IBM's X-Force Red
- Lego
- Mattel
- Nintendo
- Sony
- Wonder Workshop



For all the fun that [smart toys] can bring, there is a risk—poorly secured Internet of Things toys can be turned into convenient tools for hackers.

— Siddharth Venkataramakrishnan,
Financial Times

What to Detect When You're Expecting

This brochure will help you prepare for a healthy pregnancy and navigate the vast features of the Remote Autonomous Diagnostics (RAD) program. Each feature of the RAD program is designed to ensure the healthiest pregnancy that technology can provide:

eSkins

Vital signs—including continuous EKGs of your unborn child—are captured through small, wearable electronic skins. These eSkins also detect your level of exposure to hydrocarbons and other harmful air pollutants, and warn you when your exposure is approaching safety thresholds. The RAD program includes a subscription service that will automatically ship eSkin refills to your home. Each should last a week and can be worn consistently 24 hours a day—even while showering and exercising.

Personal digital assistant

Your digital assistant will monitor your voice and speech patterns to identify any cardiovascular or respiratory issues that may arise during pregnancy. Vocal biomarkers can also detect emerging mental health concerns. Your digital assistant monitors ambient conversation and tracks your voice as you move around your home.

Smart bathroom features

Your smart toilet can test urine with each “visit” and check levels of glucose, protein, ketones, bacteria, and blood cells. Your hydration levels will also be assessed to make sure your fluid intake is sufficient. Other outputs can also be tested, and chemical analysis can identify gastrointestinal disease and nutritional deficiencies. All test results are automatically forwarded to the AI OB service you selected during registration, and our program uses this data to guide recommendations for dietary changes that are forwarded to your smart kitchen and grocery delivery service.

Your connected mirror performs daily breath analysis, which can reveal early symptoms of gestational diabetes, test liver and kidney function, and detect airway inflammation.

Sleep monitoring

Sleep is vital to a healthy pregnancy, and the RAD program monitors it using low-energy

radar embedded in your digital assistant.

Radar is perfectly safe for you and your baby, and it can differentiate between you and your partner to detect any breathing abnormalities you may have. You will receive a sleep report each morning, along with recommendations for improving sleep quality. These changes may be reflected automatically in your nutrition plan or in time limits on electronic devices.

Personal ultrasounds

The handheld wireless ultrasound device connects directly to the RAD app, which will guide you on using the wand to perform a self-examination. Algorithms will immediately calculate key measurements during the exam to ensure clear image capture. As your pregnancy progresses, your AI OB's advanced machine learning capabilities can even track developmental progress from images of your baby's facial features.



Video of your precious bundle is immediately available and can be posted automatically to the metaverse, if desired.

Thank you for choosing the RAD program as your partner in this joyful experience. Rest assured we are monitoring everything for you, so you can relax and enjoy this time of hopeful expectation.

4TH YEAR ON THE LIST

Digital Addiction



Leaked internal Facebook research confirmed our fears about the corrosive nature of social media on teens.

KEY INSIGHT

Digital products are built to drive user engagement with habit-forming features that keep users scrolling, but research warns of the negative implications for mental health and well-being.

EXAMPLES

In September 2021, a Wall Street Journal investigation published internal Facebook research that linked Instagram to negative mental health effects for teens. The findings sparked a U.S. Senate subcommittee hearing, where Facebook released annotated decks that denied any causal links. The Facebook hearing sparked House Republicans in late October to request internal research from Snap, TikTok, and YouTube exploring the impact of their products on mental health in teens and a separate Senate subcommittee hearing. Despite Instagram announcing features that month to nudge teenagers away from certain content and prompt them to take a break from the platform, concerns persist. In December, an international coalition of over 300 scientists published an open letter to Meta CEO Mark Zuckerberg requesting access to the company's research so that outside researchers could investigate the effects of the company's products on mental health.

DISRUPTIVE IMPACT

Current efforts by social media platforms heavily rely on teenagers to opt in to features like Instagram's "Take a Break" reminders and Daily Limit tools. Other platforms, including TikTok, offer mental health resources but have not made substantial changes to the underlying algorithms that drive user engagement. Governments are starting to step in with regulation to mitigate some of the negative effects. In the U.K., an online safety bill being considered would hold tech companies accountable for protecting users from harmful user-posted content. U.S. state attorneys general launched an investigation in November into whether Meta violated consumer protection laws by promoting its apps to young users despite research pointing to mental health harms. The landscape is shifting, and tech platforms may be forced to make material changes to their products.

EMERGING PLAYERS

- Center for Humane Technology
- Facebook
- Instagram
- Twitch
- TikTok
- World Health Organization



32% of teen girls said that when they felt bad about their bodies, Instagram made them feel worse.

— Finding from an internal Facebook report

3RD YEAR ON THE LIST

Sports Tech



AxGen's DNA test identifies genes it has linked to sports injuries to create a personalized injury risk profile.

Photo Credit: AxGen

KEY INSIGHT

In a world where differences in performance are measured in tiny increments, athletes and teams are looking to technology to gain a competitive edge. The emergence of new sensors and advances in artificial intelligence and machine learning seek to quantify every aspect of sports. This technology is shifting into colleges and academy feeder programs as players and teams compete to stand out.

EXAMPLES

Dutch startup SportsTalentVision created Jogo, a sensor-enabled insole used in soccer cleats to capture metrics such as speed, acceleration/deceleration, time on ball, shot power, and right/left leg asymmetries. Jogo is similar to the Adidas GMR insoles launched in 2020 and the more recent Playermaker, which was adopted by FIFA's Innovation Programme. VERT, a wearable designed to prevent knee injuries by tracking jumps and training volume for volleyball players, also prevents shoulder injuries in swimmers by monitoring body roll and stroke count. In the weight room, Perch uses computer vision to provide detailed feedback on form and load and was adopted by the New Orleans Saints. Strive integrates electromyography sensors integrated with clothing to assess muscle performance, fatigue level, and injury risk, helping teams proactively adjust training. Controversially, startup AxGen offers a DNA test that looks for key genomic markers of specific injury risk that can sideline a prospect.

DISRUPTIVE IMPACT

Investment in sports tech is increasing, and the technology is becoming more mainstream. Berlin-based investment firm leAD funds early-stage sports tech startups with a portfolio valued at \$135 million. Sports drink Gatorade entered the market with the launch of its first wearable Gx Sweat Patch, meant to inform hydration strategies. As professional teams and leagues continue to adopt technology, expect to see greater investment in holistic performance measurement platforms that incorporate biometric and genetic marker data on top of increased granularity in functional data. Sports performance company Orreco already uses AI/ML models to develop athlete profiles based on clinical biomarkers and can combine them with game statistics. Athletic performance is being broken down into a science of data, and these models are leading the way.

EMERGING PLAYERS

- Orreco
- Scarlet Health
- AxGen
- Playermaker
- Sharper Sense
- ShotTracker

3RD YEAR ON THE LIST

Kids Fitness and Educational Games



KEY INSIGHT

Parents are looking for ways to make screen time healthier and more productive for children, and that means using games to encourage more physical activity and movement along with using gamification to teach skills like coding.

NEX Active Arcade uses motion-tracking games to get kids more active.

Credit: NEX

EXAMPLES

Motion entertainment startup NEX Team launched Active Arcade in September 2021, timed with the announcement of its \$25 million Series B round. The motion-tracking game is designed to get kids and adults moving, and requires only a camera-enabled device such as a smartphone. Fitbit launched an update to its Fitbit Ace tracker designed for kids. The device tracks activity and sleep but stays away from calorie or weight tracking. Erase All Kittens and Hopscotch are two platforms focused on teaching kids coding through games. Gaming platform Roblox introduced a \$10 million set of grants to support projects that incorporate education into games. The company aims to have 100 million students learning on Roblox by 2030.

DISRUPTIVE IMPACT

Gaming is one way to encourage kids into healthier activities and lifestyles. Some in the industry have also increased their focus in making games safer for kids. Epic Games announced that its parent verification services would be free for all developers to incorporate. While this particular area of games seeks to create healthier kids, China is tightening controls on all games for children, limiting play to three hours on the weekends.

EMERGING PLAYERS

- NEX Team
- Roblox
- Erase All Kittens
- Hopscotch

2ND YEAR ON THE LIST

Protecting Little Gamers



Parents and privacy advocates are increasingly concerned about the data being collected when their children play with connected toys and games.

KEY INSIGHT

Connected toys and games require data to work properly, and privacy experts are concerned about how children's data are being collected, used, and safeguarded.

EXAMPLES

In the U.S., the Children's Online Privacy Protection Act (COPPA) makes it illegal to collect data from children under the age of 13 without first obtaining a parent's consent, and in 2017 the Federal Trade Commission updated COPPA guidelines to specifically include toy manufacturers. For connected toys, the terms of service are shown during setup, but most people don't read the fine print. As a result, they are agreeing to data sharing, whether they realize it or not.

DISRUPTIVE IMPACT

The privacy risks posed by connected toys mirror those adults face whenever using phones, smart cameras and speakers, and other connected devices. But our tolerance for data exposure shifts when children are involved. The smart toy industry is growing rapidly—some estimate the market could be worth more than \$18 billion by 2023. But privacy regulation is lagging behind technological innovation.

EMERGING PLAYERS

- Federal Trade Commission
- Mozilla
- U.S. Public Interest Research Group

How these trends impact your company



STRATEGY

As we enter year three of the global pandemic, executive teams must make critical decisions about whether to champion a permanent hybrid workforce or to recentralize operations. Strategy executives should find a balance between near and long-term upskilling, operations, and technology implementation. For those in the retail sector, tectonic shifts are underway now that blur the lines between digital and physical experiences. Beyond offering digital versions of consumers' favorite items, brands should build features and utility into their digital catalogs. Uncertainty could breed inaction in many companies—now is a good time to invest in bold ideas and measured big bets.



INNOVATION

The intersection of work, culture, and play unlocks tremendous opportunities for innovation teams. From new product development to experimentation in distributed office structures to completely reimagining their industries, creative risk takers are in a position to shape the future of fashion, games, beauty, and toys. Chief innovation officers should lean in to all this disruption and champion thinking across longer-term time horizons within their organizations.



R & D

So much innovation is already happening in cannabis and microdosing communities; if regulators lift federal restrictions on the sale of certain substances, there will be a flood of new opportunities to develop consumer products. This year, some R&D teams might develop moonshot ideas and innovation road maps on paper, to prepare for a regulatory change. Meanwhile, there will be heightened demand for immersive video games and gaming options that span different device types.



GROWTH

The work-from-anywhere trend has unlocked business growth across many sectors, from home office equipment and lighting to high-speed broadband. What are the next-order products and services consumers might need, and how will hybrid workforces evolve over the next several years? Businesses should map plausible scenarios in 2022 to discover inflection points on the horizon.

Key Questions

We recommend using this report to support your strategic foresight activity in the coming year. Every executive team should begin by asking these questions:

1

- ▶ Is our company effectively tracking disruptive forces impacting the future of work, culture, and play?

- ▶ Do our employees understand this position?

- ▶ Which trends require a deeper understanding?

2

- ▶ How should our organization reimagine our physical and digital workspaces?

- ▶ Some teams may first need to ask: Do we even have a data hygiene or data governance policy?

- ▶ Can we develop hybrid entertainment and cultural experiences that can flex and scale along with technology?

3

- ▶ How does the growth of digital fashion, NFTs and eSports inform our business?

- ▶ If we sourced more data, could we develop new insights about our customers?

- ▶ What knock-on effects can we leverage for growth?

Selected Sources

<https://blog.google/outreach-initiatives/entrepreneurs/16-founders-disabilities-using-technology-good/>

<https://www.theinformation.com/articles/a-startup-dives-into-the-social-to-ken-pool-tiktok-expands-tipping>

<https://en.psg.fr/esports/academy>

<https://www.statnews.com/2021/10/13/apply-hipaa-facebook-transform-mental-health-for-good/>

<http://theconversation.com/wearable-tech-at-the-olympics-how-athletes-are-using-it-to-train-to-win-163860>

<https://www.wired.com/story/coding-games-for-kids-girls/>

<http://www.businessinsurance.com/article/20211207/NEWS06/912346423/BRP-Group-Inc-adds-cannabis-management-liability-insurance-program>

<https://www.natlawreview.com/article/delta-9-thc-products-hemp-are-risk-not-worth-taking>

<https://www.euronews.com/next/2021/12/07/discord-subscription>

<https://www.indeed.com/lead/preventing-employee-burnout-report>

<https://www.gamedesigning.org/schools/varsity-esports/>

<https://www.bakertilly.com/insights/esports-in-higher-education-key-considerations>

<https://www.finextra.com/newsarticle/38198/walletmor-rolls-out-payment-implants>

<https://www.gather.town/>

<https://www.businessinsider.com/microsoft-e3-2021-xbox-game-pass-2021-6>

<https://www.cnn.com/2021/03/01/gatorade-launches-gx-sweat-patch-that-measures-sweat-hydration-levels.html>

<https://www.gwoop.com/>

<https://www.lexology.com/library/detail.aspx?g=76cec-ccc-22d7-4579-a55b-840571afe8d2>

<https://www.yalemedicine.org/news/ketamine-depression>

<https://www.cbinsights.com/research/report/big-tech-famga-creator-economy/>

<http://wired.me/technology/the-great-biohack-future-human-performance/>

<https://about.fb.com/news/2021/07/investing-1-billion-dollars-in-creators/>

<https://www.bloomberg.com/news/articles/2021-09-23/facebook-fb-big-to-bacco-moment-internal-mental-health-research>

<https://www.vox.com/the-goods/2021/3/16/22332680/new-new-creator-economy-pearpop>

<https://hbr.org/2020/12/the-creator-economy-needs-a-middle-class>

<https://hbr.org/2021/09/a-labor-movement-for-the-platform-economy>

<https://www.statnews.com/2018/09/24/ketamine-clinics-severe-depression-treatment/>

<https://thehill.com/policy/technology/582227-state-attorney-generals-launch-probe-into-instagram-impact-on-children>

<https://www.cnn.com/2021/06/02/guild-education-reaches-3point7-billion-valuation-amid-labor-shortage.html>

<https://www.irishtimes.com/business/technology/technology-helps-female-athletes-achieve-unthinkable-results-1.4717072>

<http://hrexecutive.com/how-macys-hopes-to-drive-employee-retention-with-upskilling-effort/>

<https://social.techcrunch.com/2021/05/19/mapping-out-one-ed-tech-companys-200m-bet-on-lifelong-learning/>

<https://restaurantbusinessonline.com/technology/delivery-company-waitr-launch-weed-delivery-marketplace>

<https://www.rollingstone.com/culture/culture-features/psychedelic-psilocybin-smoking-quit-study-federal-funding-1255524/>

<https://www.hopkinsmedicine.org/psychiatry/about/news/media.html>

<https://www.nasef.org/events/microsoft-esports-teacher-academy/>

<https://www.voguebusiness.com/companies/navigating-the-creator-economy-gold-rush>

<https://sens.ai/product>

<https://health.ucsd.edu/news/releases/Pages/2021-02-17-new-grant-funds-clinical-trial-to-assess-psychedelic-as-treatment-for-phantom-limb-pain.aspx>

Selected Sources

Nobre, Anna C., Anling Rao, and Gail N. Owen. "L-Theanine, a Natural Constituent in Tea, and Its Effect on Mental State." *Asia Pacific Journal of Clinical Nutrition* 17 Suppl 1 (2008): 167–68.

<https://www.nature.com/subjects/nutrigenomics>

<https://nyulangone.org/news/nyu-langone-health-establishes-center-psychedelic-medicine>

<https://www.orreco.com/post/orreco-announces-3-6-million-investment-led-by-true-ventures>

<https://www.commerce.senate.gov/2021/9/protecting-kids-online-facebook-instagram-and-mental-health-harms>

<https://www.npr.org/2021/08/30/1032489883/china-kids-video-games-limits>

<https://www.statnews.com/2021/10/26/psilocybin-patent-highlights-swirling-battle-over-psychedelics-intellectual-property/>

<https://www.statnews.com/2021/11/09/largest-psilocybin-trial-finds-psychedelic-effective-treating-serious-depression/>

<https://www.statnews.com/2021/11/09/largest-psilocybin-trial-finds-psychedelic-effective-treating-serious-depression/>

<http://agriculture.infoagro.com/news/2021/rck-signs-multi-million-dollar-deal-with-holland-s-seedtech-to-provide/>

<https://www.sciencedaily.com/releases/2021/10/211027150746.htm>

<https://finance.yahoo.com/news/sens-ai-revolutionary-brain-training-183500464.html>

Seshadri, Dhruv R., Mitchell L. Thom, Ethan R. Harlow, Tim J. Gabbett, Benjamin J. Geletka, Jeffrey J. Hsu, Colin K. Drummond, Dermot M. Phelan, and James E. Voos. "Wearable Technology and Analytics as a Complementary Toolkit to Optimize Workload and to Reduce Injury Burden." *Frontiers in Sports*

and Active Living 2 (2021): 228.

<https://labusinessjournal.com/news/2021/may/21/snap-has-paid-spotlight-users-130-million/>

<https://newatlas.com/sports/jogo-soccer-performance-sensor/>

<https://www.timesofisrael.com/step-up-israeli-shoe-tracking-start-up-playermaker-joins-fifa-innovation-program/>

<https://restofworld.org/2021/innovating-for-the-worlds-largest-minority/>

<https://www.appannie.com/en/insights/market-data/evolution-of-social-media-report/>

Tullis, Paul. "How Ecstasy and Psilocybin Are Shaking up Psychiatry." *Nature* 589, no. 7843 (January 27, 2021): 506–9.

Tutty, Erin, Chriselle Hickerton, Bronwyn Terrill, Belinda McClaren, Rigan Tytherleigh, Elaine Stackpoole, Jaqueline Savard, et al. "The Expectations and Realities of Nutrigenomic Testing in

Australia: A Qualitative Study." *Health Expectations : An International Journal of Public Participation in Health Care and Health Policy* 24, no. 2 (April 2021): 670–86.

<https://www.miningmagazine.com/innovation/news/1409669/wenco-acquires-smartcap>

<https://www.merrco.com/blog/banking-act-safe-2021-cannabis/>



News & Information

Tech trends influencing the future of journalism, media, and the business models supporting entertainment and news.

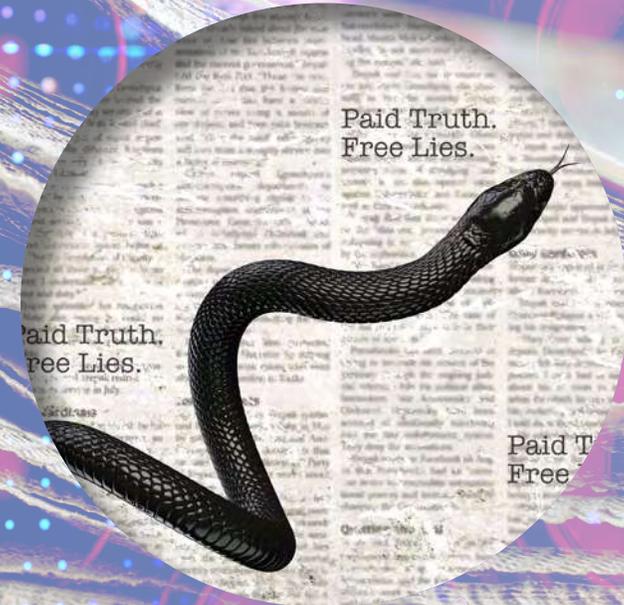


Table of Contents

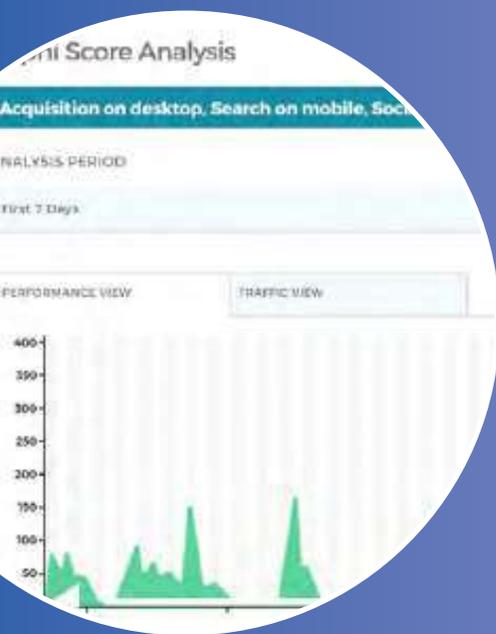
238	Key Insights	263	Application
239	Computer-Directed Reporting	264	Key Questions
240	Dateline: Metaverse	265	Selected Sources
242	Digital Threat Modeling		
243	Evolving Search Interfaces		
244	Scenario: We're Hiring!		
245	Subscription Economy Matures		
246	Eroding Trust in News Organizations		
247	One-to-Few Networks		
249	The First Amendment in the Digital Age		
250	Scenario: Reporting Live From the Metaverse		
251	Digital Frailty		
252	Sensory Journalism		
253	Teaching News Literacy		
254	Policing the Creator Economy		
255	Attention Metrics		
256	Investigating Technology		
257	Media Consolidation		
259	Cancel Culture and Accountability Politics		
260	Scenario: No News Is Bad News		
261	Geography Reshapes the Virtual World		
262	Journalism-as-a-Service		

Key Insights

- * Metaverse datelines are coming. (Example: ROBLOX—The Republican National Convention began ...)
- * Journalists need to decide how to cover newsworthy events and avatars as people spend more time in virtual spaces.
- * Selling digital subscriptions creates new opportunities for media companies looking to find their niche.
- * A growing number of startups are providing artificial intelligence solutions to newsrooms.
- * Natural language search interfaces—whether deployed in AI assistants or as a feature in browser-based search engines—threaten the audience strategy for many media organizations.
- * Sensory clickbait, designed to manipulate a user's emotions, is on the rise.
- * Media literacy programs are launching around the world, in an effort to curb misinformation among kids and teenagers.
- * Social media has created supercharged cycles of outrage, boycott, and backlash.
- * Media consolidation threatens communities, which are losing their only source of local news coverage.

1ST YEAR ON THE LIST

Computer-Directed Reporting



Sophi uses AI to automate homepage production and paywall logic for news organizations.

KEY INSIGHT

Computer-directed reporting applies natural language processing (NLP) algorithms and artificial intelligence to automate many common tasks like curating a homepage and writing basic news stories. As these tools mature, they'll let newsrooms reassign staff toward creating journalism—or pursue more aggressive cost cutting.

EXAMPLES

A growing number of startups are providing AI solutions to newsrooms. Sophi offers a bundle that automates homepage production and makes user-level decisions about when to serve a paywall. The Globe and Mail, which created Sophi as an internal tool and spun it out as a stand-alone B2B product, has automated 99% of site curation, trusting the algorithm to do the work as well (or better) as editors.

The Associated Press has automated the production of some corporate earnings stories for nearly a decade. The San Francisco-based startup Knowhere News publishes more than 100 fully automated newsletters in California, Florida, and Ohio. In 2020, a U.K. team of five journalists at RADAR (Reporters And Data And Robots) produced more than 140,000 stories and 55 million words using AI.

DISRUPTIVE IMPACT

As NLP algorithms grow more powerful, they'll be useful for more editorial tasks. Computer-directed reporting could let human journalists focus on higher value reporting—or it could justify layoffs.

News organizations face an ethical void when adapting journalism-producing AI systems. How should editors detect bias in an algorithm? How should an error made by a natural language generator be corrected? Can AI really know what's newsworthy? Should an AI system replace human judgment for information consumed by millions of people?

The urgency for answering these questions is heightened because technology companies, not journalists, drive much of the innovation in this space. Knowhere News acknowledges that its systems can only capture what's in existing sources, such as press releases and social media posts. "We don't have one side and the other side in an individual story," Knowhere Managing Editor Christopher Noble told *The Information*. "It is a potential weakness to what we can do."

EMERGING PLAYERS

- Automated Insights
- Arkadium
- Cortico
- Crosstown
- Knowhere News
- Primer
- RADAR (Reporters And Data And Robots)
- Sophi
- United Robots
- SenseTime
- Scale AI
- Syntiant

1ST YEAR ON THE LIST

Dateline: Metaverse



In 2020, the Norwegian government hosted a virtual Constitution Day parade on Minecraft that attracted 37,000 participants.

KEY INSIGHT

While most news organizations today treat metaverse platforms as part of the gaming beat, we're seeing signals that those spaces will be used to reach voters and organize political action. Journalists need to decide how they cover newsworthy events and avatars as people spend more time in virtual spaces.

EXAMPLES

During the New York City mayoral primary, an avatar of Andrew Yang made a campaign appearance in the Zepeto metaverse. The virtual event reached a small audience and was primarily covered on gaming websites but raised important questions about how mainstream media would respond if Yang broke news on a virtual platform.

The Norwegian government hosted a virtual Constitution Day parade on Minecraft in May 2020 that attracted 37,000 participants. Aftenposten, a major Norwegian newspaper, wrote a brief article about the event using statistics published by the Constitution Day organizers. When U.S. Reps. Alexandria Ocasio-Cortez and Ilhan Omar played “Among Us” live on Twitch, they reached more than 5 million people and generated headlines in mainstream media—but no sustained coverage of the political organizing and engagement happening appeared in nontraditional spaces.

DISRUPTIVE IMPACT

As investment in the metaverse accelerates, expect to see more celebrities, politicians, and corporations make a play to reach audiences in virtual spaces. Because it's easy to hyper-target interest groups based on which digital communities they belong to, messages posted to metaverse spaces may not match what happens in the real world—or in a different online community.

Journalists need to start thinking about how they will cover entities that pander at scale: How will they report on contradictory statements online and in real life? Which version of a statement is authentic—the one made by an avatar or the one made standing behind a physical podium?

News organizations should also start thinking about their long-term value proposition: If more of our life happens on platforms with built-in archiving and playback capabilities, does a journalist's role need to shift away from telling people what happened?

EMERGING PLAYERS

- Zepeto
- Fortnite
- Meta's Horizon Worlds



A True Fan is defined as someone who will purchase anything and everything you produce. They will drive 200 miles to see you sing. They have a Google Alert set for your name. They bookmark the eBay page where your out-of-print editions show up. They come to your openings. They have you sign their copies. They buy the t-shirt, and the mug, and the hat. They can't wait till you issue your next work. They are true fans.

— Kevin Kelly



1ST YEAR ON THE LIST

Digital Threat Modeling



The Block Party app helps journalists mitigate the impacts of digital harassment.

KEY INSIGHT

Journalists and activists have a heightened risk profile in the digital world. Bad actors and governments that want to interfere with their work can wreak havoc by hacking, harassing, and doxxing.

EXAMPLES

The world saw a record number of zero day exploits—previously unknown cybersecurity vulnerabilities—in 2021, according to MIT Technology Review. Those attacks can be leveraged against all kinds of targets, but we’ve seen multiple instances of weapons grade hacking, like the NSO Group’s zero-click Pegasus spyware, being deployed against journalists and activists.

Reporters who publish on controversial subjects can find themselves subjected to organized harassment campaigns—especially if they are women or part of a visible minority. A 2021 report commissioned by UNESCO found that the weaponization of social media against journalists disproportionately impacts women, can cut across platforms and into the real world, and can operate in concert with broader misinformation campaigns that undermine trust in media.

DISRUPTIVE IMPACT

Hacking and harassment can block journalists from doing the work they need to do and subject them to tangible harm—both psychological and physical. Mitigating those threats takes preparation and common sense: Steps like enabling two-factor authentication on work and personal accounts, regularly auditing what personal information is available online, and keeping up with software updates can go a long way toward staying safe.

EMERGING PLAYERS

- Block Party
- Google’s Threat Analysis Group
- Kaspersky’s Global Research & Analysis Team
- International Press Institute’s OnTheLine
- Microsoft’s Threat Intelligence Center

5TH YEAR ON THE LIST

Evolving Search Interfaces



A growing number of consumers are using non-text searches to find information.

KEY INSIGHT

Searching for information is increasingly flexible, with advances in voice interfaces allowing consumers to speak their search while image recognition algorithms let users search with their camera. Whether embedded in a wearable device, phone, or smart speaker, non-text searches can deliver more relevant results than traditional text-based queries.

EXAMPLES

A 2019 survey of internet users worldwide found that 42% had conducted a voice search in the previous month. Such queries are most popular in Asia-Pacific emerging markets.

Pinterest is a leader in visual search. Fine-tuning its systems since 2015, Pinterest can recognize objects within images, letting users search for items they see in the real world from a picture they took and offering meaningful recommendations with a product called Guided Search.

Another emerging search interface is natural language search. In June 2021, four engineers from Google's research division published a paper proposing a search experience that synthesized answers from scratch, rather than displaying results for users to pick from. Such a search engine would be immensely useful to users—but tremendously disruptive to businesses that rely on search traffic.

DISRUPTIVE IMPACT

Natural language search interfaces—whether deployed in AI assistants or as a feature in browser-based search engines—threaten the audience strategy for all kinds of media organizations: Natural language search requires a completely different type of search optimization. To maintain existing traffic levels, publishers need to consider how their structured data models will support audio and image search.

Because natural language queries tend to yield only one result, the risks to media outlets or e-commerce sites that fail to optimize for search are profound—especially as consumers become more comfortable making purchase decisions through voice interfaces.

The growth of non-text search could create an opportunity to challenge Google's dominance in search. Unlike traditional search engines, which aim to index everything, visual searches may be more specialized: One portal might excel in recognizing clothing, while another might help identify real-world locations.

EMERGING PLAYERS

- Instagram
- Listen Notes
- Pinterest
- Wonderly

The Springfield Gazette

We're Hiring!

Computer Directed Reporter

Where: Remote

We are looking for an ambitious reporter to join our growing newsroom at the direction of our industry-leading AI editor, Nellie.

By combining open-source information from social media, government websites, and community groups with our proprietary data and models, Nellie optimizes how our human reporters spend their time, contact sources, and frame their writing. Nellie is tuned to help human journalists craft newsworthy stories that are engaging and newsworthy. Like its namesake, Nellie Bly, our AI editor has a best-in-class ability to find stories that resonate with audiences.

It's easy to submit your reporting portfolio to Nellie through our online portal. If your portfolio is a good fit, Nellie will schedule a virtual writing test. Because our audience's trust is essential, all applicants must pass a background check (including an encrypted scan of all social media profiles, text messages, and personal email) conducted by the industry-standard ethics bot AI-ristotle.

Responsibilities

- Report and write 2-5 daily stories, as directed by Nellie
- Consistently and simultaneously meet deadlines on breaking news and enterprise articles
- Develop sources that can submit information directly to Nellie
- Effectively execute Nellie's recommendations with regard to story framing, headlines, story length, and distribution strategy

Qualifications

- At least 5 years of professional journalism experience, at least 2 under direction of an AI editor
- Unimpeachable journalistic integrity and judgment, as measured by our ethics bot AI-ristotle.
- Digital fluency with the tools required to edit, produce, and curate content on all platforms
- Ability to move ideas quickly from concept to completion
- Demonstrated knowledge of complex social and cultural issues
- Self-starter with proven ability to meet deadlines while paying close attention to the cues of an AI editor
- Ability to manage several assignments concurrently

3RD YEAR ON THE LIST

Subscription Economy Matures



KEY INSIGHT

Digital subscriptions create new opportunities for media companies looking to find their niche. The proliferation of subscriptions in news arrives alongside a broader shift away from ownership.

Pivoting to subscriptions is helping news organizations stay afloat; that shift is part of a larger reorientation away from ownership.

EXAMPLES

Advertising revenue evaporated as COVID-19 swept across the world in early 2020. While those economics would have been catastrophic for many news organizations just a few years ago, the pivot to subscription and membership programs over the last several years gave many newsrooms a stable revenue stream through the pandemic.

It's not just new companies that are turning to subscriptions, however. More than a fifth of U.K. retailers launched a subscription program during COVID lockdown, according to Barclaycard—making it so nearly half of retailers in the U.K. have a subscription.

DISRUPTIVE IMPACT

Subscriptions' stable revenue streams are not a panacea. As the economy transitions away from ownership, there is more competition for share of wallet. Because many publishers grew their digital subscriber base with aggressive discounting, preventing churn becomes an essential task. Without entrepreneurial thinking and business model innovation, news organizations may not keep up.

Subscriptions also change the relationship between publishers and their audiences: As paywalls tighten, there's a real risk that accurate, timely information becomes concentrated in the hands of the wealthy.

EMERGING PLAYERS

- The Membership Puzzle Project
- Piano
- Pico

8TH YEAR ON THE LIST

Eroding Trust in News Organizations



Trust in all media has been falling globally since 2018.

KEY INSIGHT

Trust in all media has been falling globally since 2018, according to the Edelman Trust Barometer. The trust crisis is amplified as search and social distribution continue fraying relationships between news organizations and audiences. News leaders should be particularly attuned to external forces and events that might exacerbate this trend.

EXAMPLES

A majority of people globally believe that journalists are purposefully trying to mislead the public, according to the 2022 Edelman Trust Barometer survey. People generally report higher levels of trust in the news they consume relative to the overall media, according to the 2021 Reuters Digital News Report. But the same report finds that consumers across the world report lower trust in information they get from search and social media. That's a big problem for news organizations, because that's where a big portion of their users—and a disproportionate share of their new users—come from.

A variety of factors contribute to the growing distrust in news, ranging from the growing visibility of intentional misinformation campaigns and conspiracy theories on social media to increasing political polarization. While platform companies continue to refine their rules for deleting, demonetizing, or reducing the reach of misleading, fake, or controversial posts, those actions are unlikely to stem the tide of this trend.

DISRUPTIVE IMPACT

News organizations live and die by their reputation. If a title loses the trust of its audience, it loses the ability to sell subscriptions and advertisements.

A trust crisis might be triggered by a routine mistake in reporting or by a politician angry about a true—but unflattering—story. There's also a risk that audiences lose faith in the news for something outside of a news organization's control: A manipulated video circulating on social media could impact consumer attitudes toward all kinds of media.

EMERGING PLAYERS

- Reuters Institute for the Study of Journalism
- American Press Institute
- Consortium on Trust in Media and Technology at the University of Florida

8TH YEAR ON THE LIST

One-to-Few Networks



Journalist Daniel Levitt publishes “Inside the Newsroom,” one of the most popular newsroom-focused newsletters on the Substack platform.

KEY INSIGHT

Low-cost tools to produce newsletters, podcasts, and niche experiences are enabling individuals to create personal media brands. These products can super-serve an audience but can also be a powerful vector for disinformation and misinformation because they don’t have the editorial safeguards that protect traditional media.

EXAMPLES

Email platform Substack has lured a slew of big name journalists away from traditional gigs. It’s also committed \$1 million to support independent creators wanting to launch local news newsletters in the U.S. Ghost is an open-source alternative to Substack. Some one-to-few networks bring together multiple ways to connect their community, like Sidechannel, a Discord server for paid subscribers to several technology newsletters.

While these networks create new opportunities to connect audiences, they’re not free from risk: Creators and communities who rely on platforms to connect can be vulnerable when those platforms fail. When Facebook services went offline for more than six hours in October 2021, activists and families in large parts of the world lost their ability to connect because WhatsApp was inaccessible.

DISRUPTIVE IMPACT

The technologies that enable one-to-few networks lower the barrier to entry for new competitors to legacy media—or for disgruntled creators who want to strike out on their own.

One-to-few networks will be a major front in ongoing efforts to confront disinformation and misinformation. The same technology that empowers neighborhood-level “buy nothing” groups to cut down on waste and unnecessary consumption can allow networks of white supremacists to plan acts of domestic terror.

EMERGING PLAYERS

- Discord
- Ghost
- OnlyFans
- Patreon
- Substack
- Zello



Black journalists continue to be underrepresented in newsrooms today, and Black stories continue to go overlooked and undercovered. We're building trust among Black audiences with quality, trustworthy journalism.

— Lauren Williams, CEO and Cofounder, Capital B



7TH YEAR ON THE LIST

The First Amendment in the Digital Age



WhatsApp is one of many platforms that enable small networks to share information.

KEY INSIGHT

The First Amendment offers broad protections for what individuals and companies in the United States can do, leaving plenty of room for debate about what they should do. That tension is opening up new paradigms for how content is regulated and moderated online.

EXAMPLES

Increased scrutiny has led mainstream platforms to take a more aggressive posture toward removing speech that violates their terms of service. Facebook removed more than 20 million posts containing COVID-19 misinformation from its app and Instagram between the start of the pandemic and June 2021. Even former President Donald Trump's unlaunched Truth Social network has lines for speech: Its terms of service give the site permission to remove posts that “disparage, tarnish, or otherwise harm, in our opinion, us and/or the site.”

In a Columbia Law Review article, lecturer Evelyn Douek argues that our approach to online speech has reached an inflection point: Instead of privileging the rights of individuals to post without restriction, “platforms are now firmly in the business of balancing societal interests and choosing between error costs on a systemic basis.”

DISRUPTIVE IMPACT

While the First Amendment's legal protections are generally broad in the United States, its scope is limited in an interconnected world. As a result, debates about free speech now hinge on the moderation policies of private companies—entities that are not directly accountable to their users and that are free to change their rules at will.

Brands, news organizations, and political movements will struggle to find where they fit into the world built by tech companies. That will be especially true for any entity that works with potentially controversial political speech. Journalists in Gaza, for example, lost access to an essential communication platform when they were banned by WhatsApp—allegedly for engaging with groups that were inciting violence. Facebook eventually restored access for some of the journalists, but the story highlights how unpredictably users can lose access to a platform.

EMERGING PLAYERS

- American Civil Liberties Union
- Electronic Frontier Foundation
- U.S. Federal Communications Commission
- Knight First Amendment Institute at Columbia University



The First Amendment—inflected approach to online speech governance that dominated the early internet no longer holds.

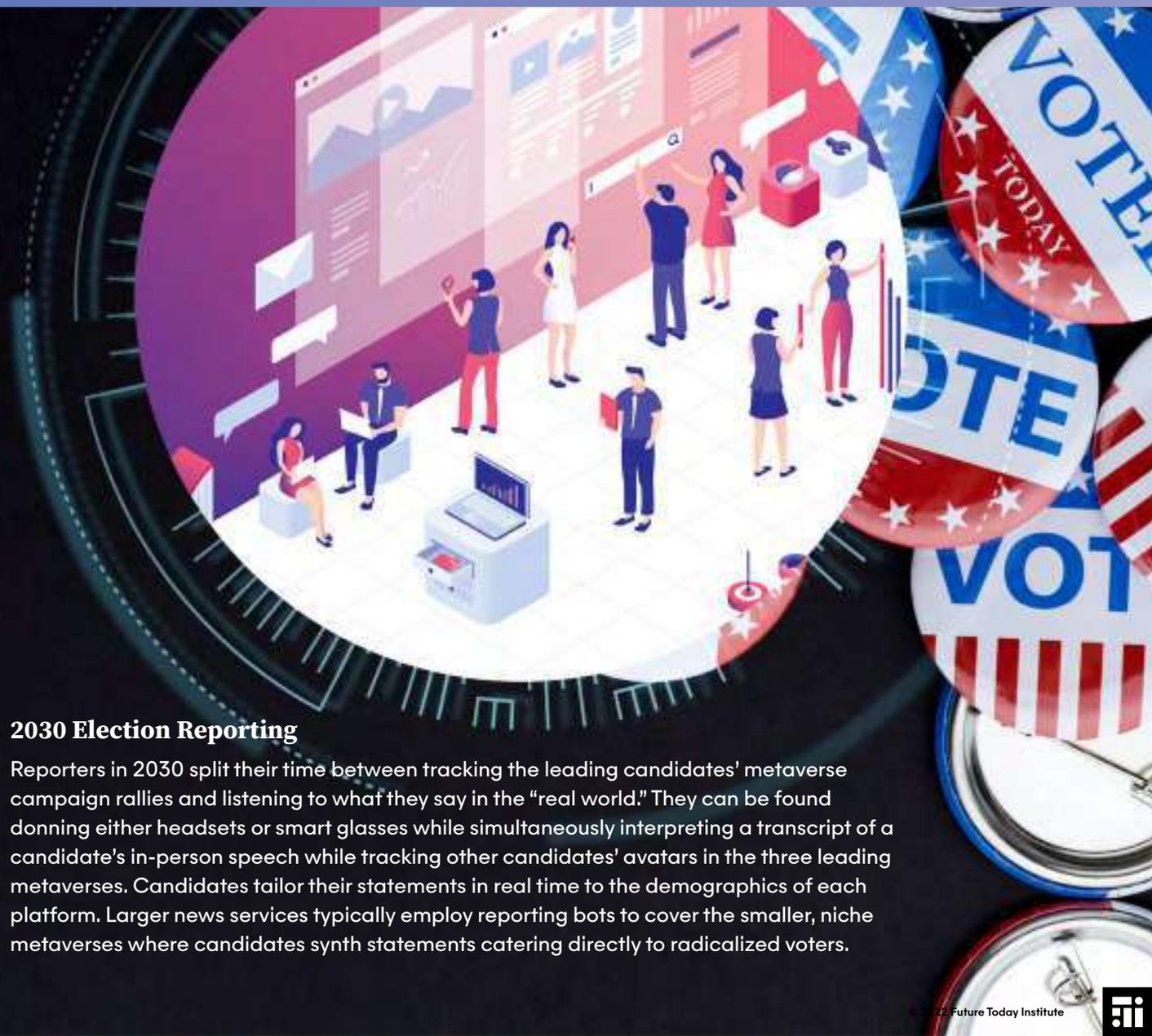
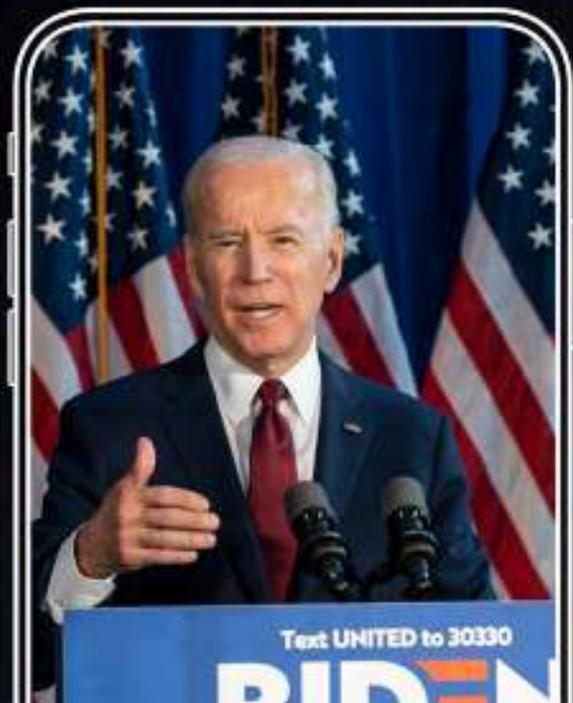
— Evelyn Douek,
Columbia Law Review

Reporting Live From the Metaverse

Political reporting shifted when candidates started campaigning in the metaverse. A look at then and now.

2020 Election Reporting

The job of a political reporter was relatively easy in 2020. It involved covering campaign rallies, riding along candidates on campaign buses, monitoring Twitter and news sites, interviewing relevant politicians and fact-checking speeches—and then filing the stories to the web.

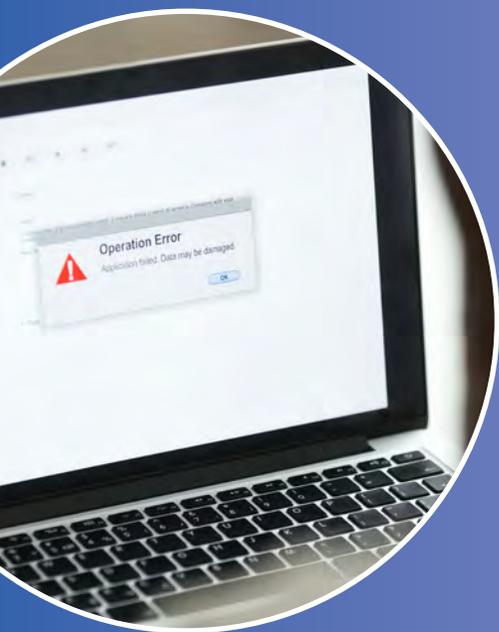


2030 Election Reporting

Reporters in 2030 split their time between tracking the leading candidates' metaverse campaign rallies and listening to what they say in the "real world." They can be found donning either headsets or smart glasses while simultaneously interpreting a transcript of a candidate's in-person speech while tracking other candidates' avatars in the three leading metaverses. Candidates tailor their statements in real time to the demographics of each platform. Larger news services typically employ reporting bots to cover the smaller, niche metaverses where candidates synth statements catering directly to radicalized voters.

7TH YEAR ON THE LIST

Digital Frailty



Without planning, critical information could be lost forever.

KEY INSIGHT

Digital frailty is the collective vulnerability we face from failing to consider the long-term consequences of losing digital archives to technical glitches, evolving file systems, or intentional design.

EXAMPLES

Dallas lost more than 20 terabytes of police files during a server migration in March 2021 because the city had no formal system for managing data storage. The mistake—triggered by a single staffer in the IT department—jeopardized 17,494 family violence prosecutions, including 1,000 priority cases.

Sometimes digital assets appear more fragile than they really are. Users tend to trust that when they click “delete” or let a social media video expire that it is actually gone. That’s not always the case: In June 2021 a researcher studying the origins of COVID recovered files that had been deleted months earlier from a National Institutes of Health database by scientists in China. The researcher was able to find early genetic sequences of COVID viruses by guessing their URL in the NIH’s cloud storage system even after public references to the files were removed.

DISRUPTIVE IMPACT

Digital frailty could deny future historians access to crucial primary sources about our time. While the Internet Archive and others try their best to create snapshots in time of the internet, those services struggle with dynamic sites that rely on JavaScript or those with highly personalized experiences like TikTok or Instagram.

But creating a comprehensive, indelible record of all digital assets could be just as risky as archiving nothing. Young people create countless amounts of data daily, from posts shared on social networks to assignments posted to their school’s digital classroom. Do young people have the right to a blank slate when they reach adulthood, or should they be held accountable for every piece of data they create on the way to maturity?

EMERGING PLAYERS

- Amazon Web Services
- Google Cloud
- Internet Archive
- Microsoft Azure

2ND YEAR ON THE LIST

Sensory Journalism



Research device Project Aria is worn like regular glasses.

KEY INSIGHT

Sensory journalism is news delivered through emerging devices like smart glasses or headphones that directly integrate with a user's senses. This will enable new ways for journalism to resonate with readers but also raises the specter of "sensory clickbait" that is designed to manipulate a user's emotions.

EXAMPLES

During a 2020 experiment, environmental researchers found that showing people a virtual reality scenario about climate change could make them feel more empathetic about the ocean's future. Other research has shown that VR experiences generate longer lasting emotional responses than text-based approaches to sharing perspectives. As the devices enabling sensory journalism become more immersive, journalists will need to examine how their work could manipulate people in unforeseen ways.

DISRUPTIVE IMPACT

While there's substantial investment in smart glasses and virtual reality headsets, the technology that will enable sensory journalism is still nascent. That means it's time to consider the thorny questions this trend poses: How will journalists ensure their work is accessible to all—including groups that tech companies frequently fail to prioritize (women, people with disabilities, and people of color)? What are the ethical guidelines for telling stories that integrate with a user's senses? By acting now, newsrooms can be proactive and act strategically.

EMERGING PLAYERS

- Meta's Project Aria

1ST YEAR ON THE LIST

Teaching News Literacy



Media literacy programs are beginning to launch in schools.

KEY INSIGHT

Thanks to technology, more information is available today than at any point in human history. But not all of it is created equally. Teaching kids how to identify reliable information will prepare them for the workplace—and avoid a future without shared facts.

EXAMPLES

Finland has made media literacy part of its national curriculum for nearly a decade. Lessons from its Ministry of Education and Culture about finding reliable information are embedded in core classes like math and history. That teaching cements Finland's place on top of the Open Society Institute's annual Media Literacy Index.

In the U.S., a number of states are requiring students to learn media literacy—the skills needed to critically analyze and interpret media messages. As of 2022, 14 states have passed legislation with such a mandate. In pockets around the country, some elementary schools teach digital literacy as early as kindergarten.

DISRUPTIVE IMPACT

“Thriving democracies need citizens who can evaluate and access reliable information,” Stanford University professor Sam Wineburg has said, yet emerging technologies threaten to further confuse young people. We’ve already seen that disinformation and misinformation can have a profound impact on our society, whether through disrupting our elections or undermining trust in the medical establishment.

If governments won't step in to provide education, news organizations will need to fill the void. The inability for citizens to agree on shared facts undercuts their business model—and the basic fabric of our society.

EMERGING PLAYERS

- Finland's Department for Media Education and Audiovisual Media
- Media Literacy Now
- News Literacy Project

1ST YEAR ON THE LIST

Policing the Creator Economy



Hype House was the first creator collective to go mega-viral on TikTok.

Image courtesy of Hype House/Instagram.

KEY INSIGHT

If you want to solve a problem, follow the money. We're seeing evidence that platforms and advertisers will use monetization as a tool for fighting misleading, fake, or controversial content.

EXAMPLES

Policies to protect advertisers from controversial or “brand unsafe” content are nothing new. But as platforms increasingly make sweeping monetization decisions to preemptively block entire categories of content or behavior, they're sending a broader message about what they want to be associated with.

Streaming service Twitch has a policy that permits banning or demonetizing a user for some behavior that happens on other platforms or in the real world. Google announced in October 2021 that it would no longer serve ads on websites and videos that deny climate change. That adds to an existing list of topics that can't be monetized on YouTube, like videos that include hate speech or non-medically approved remedies.

On the flip side, look to eye-popping funding from tech companies to bolster content on their platforms: TikTok's \$200 million Creator Fund, YouTube's \$100 million Shorts Fund, and Substack's \$1 million funding for local news, among others.

DISRUPTIVE IMPACT

Ad revenue and sponsorship are the amphetamines that drive the creator economy. When that cash flow is disrupted it can change the incentives around creating new content. That's good news for journalists and others who produce reputable websites and videos—with less sketchy players to compete with they'll have more opportunities to stand out.

But any publisher or creator on the winning side of a platform's investment decision today should be wary: Algorithm tweaks or changes in funding priorities could rewrite the rules again in a moment.

EMERGING PLAYERS

- TikTok
- Twitch
- YouTube

3RD YEAR ON THE LIST

Attention Metrics



Many people hadn't heard of Ozy Media until the company's chief operating officer impersonated a YouTube executive on an investment call with Goldman Sachs and brought attention to the company's business practices.

KEY INSIGHT

Measuring how consumers allocate their attention depends on how you count—and who is counting. As a result, publishers need to get more sophisticated about how they monetize engagement.

EXAMPLES

The metrics underpinning the attention economy are highly susceptible to fraud. One study estimated that bots make up more than 60% of all website traffic. Another found that as much as 88% of digital ad clicks could be considered fraudulent. Digital media company Ozy Media had a spectacular meltdown in 2021 after an investigation revealed the company had vastly overstated its traffic and attempted to defraud investors.

Even when businesses want to do right, the technological landscape that enables tracking and monetizing attention is unstable. Google plans to phase out support for third-party cookies in its Chrome browser in 2023. It's still unclear how advertisers and marketers will replace the functions currently served by third-party cookies and how any changes will balance the desire to track behavior against user's expectation of privacy.

DISRUPTIVE IMPACT

The attention economy encompasses news publishers, streaming services, gaming platforms, and more. Without trust in the metrics that connect individuals to their actions across the web, there is profound uncertainty for all those entities. The impending death of third-party cookies creates new urgency for digital marketers and advertisers to quantify the impact of their work—and to ensure that their partners trust their metrics: Nearly half of publishers anticipate needing to lay off staff, according to a survey of 200 decision-makers by ad tech company Lotame.

EMERGING PLAYERS

- Facebook
- Google Analytics
- Interactive Advertising Bureau
- Plausible Analytics

8TH YEAR ON THE LIST

Investigating Technology



The Markup is a nonprofit newsroom that investigates how powerful institutions are using technology to change our society.

KEY INSIGHT

News organizations need specialized reporters with the technical skills to understand how technology operates in the world—and to explain it to a nontechnical audience.

EXAMPLES

Frances Haugen's decision to leak reams of internal Facebook documents helped journalists at many news organizations better understand the social network's algorithms. One story, for example, traced the weights that Facebook assigned different emoji reactions when deciding how to rank stories in users' news feeds. That reporting helped bring specifics to the debate about how algorithmic distribution impacts society.

Major newsrooms are increasingly building teams that fuse multiple disciplines to create impactful reporting. Visual investigations teams at The Washington Post and The New York Times have used crowdsourced footage to recreate newsworthy moments from multiple angles. Tech-focused publications like The Markup have launched tools that make it easy for laypeople to see how they are tracked and targeted online.

DISRUPTIVE IMPACT

As AI-powered decisions seep into every corner of our life, investigating the algorithms making those decisions has never been more important. Technology advances make it increasingly harder for laypeople to understand how systems function—even as those systems become more deeply embedded in the fabric of our society. Investigative skills to unpack technology is essential in newsrooms, in order to serve the fundamental journalist mandate of holding the powerful accountable.

EMERGING PLAYERS

- The Markup
- Bellingcat
- The Washington Post computational journalism team
- The New York Times visual investigations team
- Tow Center for Digital Journalism at Columbia University
- Computational Journalism Lab at Northwestern University
- Online Political Ads Transparency Project at New York University

7TH YEAR ON THE LIST

Media Consolidation



In May 2021, shareholders of Tribune Publishing, one of the largest U.S. newspaper chains, approved a sale to Alden Global Capital.

KEY INSIGHT

Consolidation continues in legacy and digital media ownership. There are isolated examples of local communities coming together to save their hometown newspaper from chain ownership, but those instances haven't changed the fundamental economics that drive media consolidation.

EXAMPLES

Gannett—which grew in 2021 after its merger with GateHouse Media—owns just shy of 40% of the major daily newspapers in the United States, according to an analysis by the Institute for Quantitative Social Science at Harvard. The majority of daily newspapers are owned by just seven conglomerates.

Consolidation among digital publishers is accelerating, driven by a need to justify years-old valuations to early investors and the growing popularity of SPACs—special purpose acquisition companies that can be used to accelerate going public. While consolidation among digital properties is less disruptive to a community than a newspaper or broadcaster merging, it tends to have the same effects: layoffs and cost cutting. BuzzFeed laid off 70 employees in March 2021 after joining with HuffPost.

DISRUPTIVE IMPACT

When media companies are focused on executing complex transactions, they're distracted from the strategic imperatives they need to face. While publishers are restructuring and trying to realize synergies, the threat of empowered social media platforms and new entrants looms. It's plausible that the larger companies will have more negotiating power with distribution platforms, but it's also possible that the strategy of consolidation won't do enough to proactively mitigate external threats. Only time will tell.

EMERGING PLAYERS

- Alden Global Capital
- BuzzFeed
- Chatham Asset Management
- Vox Media
- New Media Investment Group



57% of people worry that government leaders are purposely trying to mislead people by saying things they know are false or gross exaggerations.

56% worry that business leaders are doing the same.

— 2021 Edelman Trust Barometer



3RD YEAR ON THE LIST

Cancel Culture and Accountability Politics



After Dr. Seuss' estate chose to withdraw some books from publication, a backlash to the author being "canceled" led to price surges of those books on Amazon.

KEY INSIGHT

Social media has created supercharged cycles of outrage, boycott, and backlash. But writing off something as "cancel culture" is a tool frequently used by the powerful to evade consequences for their actions. Beneath the controversy is a meaningful evolution in how we seek accountability in the world.

EXAMPLES

A group of intellectuals—many who had been "canceled"—founded the University of Austin decrying the "illiberalism and censoriousness prevalent in America's most prestigious universities." A Dave Chappelle special on Netflix stoked controversy, including a walkout of Netflix employees, because it included jokes about trans women. Tucker Carlson, one of Fox News' most prominent personalities, has emphatically embraced anti-cancel culture discourse, claiming liberals are trying to cancel everything from "Space Jam" to the Fourth of July. Brandeis University made waves (in certain corners of the internet) in June 2021 when students published a list of "oppressive" words. Later rebranded as the "suggested language list," the project aimed to "remove language that may hurt those who have experienced violence from our everyday use." Right-wing coverage of the list mocked students for "canceling" words; on the left, students were seen as standing up for their values and trying to undo harm.

DISRUPTIVE IMPACT

The discourse around cancel culture frequently breaks down around generational lines. Rather than lamenting "kids today," brands and individuals might ask why Generations Z and Alpha seem to demand different levels of accountability than previous generations. Instead of dismissing social media outrage as vapid, look to understand the power dynamics at play—is a controversy a sign of new social dynamics clashing with the status quo? The powerful trying to delegitimize an emerging movement? A disinformation campaign organized by outside actors?

EMERGING PLAYERS

- Heterodoxy Academy
- American Association of University Professors
- Modern Language Association
- National Coalition Against Censorship
- The Free Speech Project at Georgetown University

The Federal Misinformation Act of 2026

People were once convinced that paywalls would save news media—and democracy.

Yet, as more news publications increasingly locked their stories behind paywalls, the only free information available was misinformation. It wreaked havoc on institutions of knowledge and credibility. To curb misinformation with automated fact-checkers, lawmakers passed the Federal Misinformation Act

of 2026, which imposed monetary fines on content producers for violating these terms.

But the regulation came too late. By then, all reputable news was hidden behind a paywall, proving too costly for the majority of consumers. This left only two options: Read the scant misinformation available from free content publishers awaiting censure from regulators, or read no news at all.



3RD YEAR ON THE LIST

Geography Reshapes the Virtual World



In Europe, rising U.S.-China tensions sparked a movement to develop local digital capabilities.

KEY INSIGHT

We're seeing increasing evidence that a user's physical location governs how much they can participate in a digital world. Any business that relies on connecting people with information—whether it's a newsroom, social network, or e-commerce website—is impacted by this trend.

EXAMPLES

Broadband access is concentrated in urban centers. This was especially apparent in the early months of the pandemic when schools shifted to remote learning: Students in rural areas around the globe struggled to get online to complete their studies.

Privacy rights vary based on regional and national laws. Any business that serves customers across international or regional boundaries needs to contend with this patchwork of regulation.

And increasingly, governments are using access to digital resources as a way to control dissent. Human rights group Access Now documented at least 50 internet shutdowns in 21 countries between January and May 2021. "As governments across the globe learn this authoritarian tactic from each other, it has moved from the fringes to become a common method many authorities use to stifle opposition, quash free speech, and muzzle expression," Felicia Anthonio, lead campaigner for Access Now, told *The Current*, a Google-sponsored magazine.

DISRUPTIVE IMPACT

The growing complexity of connecting users and data changes the economics of operating online. For businesses, overlapping (and sometimes contradictory) regulations increase the cost of serving customers in different places. Established tech platforms and multinationals may have the scale to account for that kind of regulatory complexity, but new entrants may find it hard to serve—and monetize—audiences in multiple jurisdictions.

Newspapers, governments, and others that offer essential digital products based on the assumption of open access need to confront the possibility that geographic inequality or malicious intent could sever an audience from their work.

EMERGING PLAYERS

- Access Now
- American Telemedicine Association
- BroadbandNow
- Connect Americans Now
- Consortium for School Networking
- Broadband Europe
- U.S. Federal Communications Commission

8TH YEAR ON THE LIST

Journalism-as-a-Service



ProPublica hosts a data store where consumers (or businesses) can buy clean datasets that were produced during the nonprofit's investigative reporting.

KEY INSIGHT

News organizations are increasingly realizing that their core value proposition doesn't live in 750-word blocks of text. Publishers are scaling up their service-driven offerings, including web products that provide a service and monetized datasets collected during the reporting process.

EXAMPLES

“Journalism as a service” stems from experiments that seek to understand what consumers will pay for. The Information, a news site covering the business of technology, offers its members organizational charts of major tech companies and databases of startup investment. The Skift, a digital trade publication covering the travel sector, includes a research arm that delivers original analysis. CalMatters, a nonprofit covering California politics, launched a product that helps voters track where their state legislators stand on key issues. JaaS lets news organizations develop tentpole products that can generate revenue in a recurring way.

DISRUPTIVE IMPACT

The practice of journalism is more than the published report: The best reporters create an enormous corpus of data as they work. Finding ways to realize additional value from that work could benefit everyone in the knowledge economy—universities, legal startups, data science companies, hospitals, and even tech giants. Because journalists are trained to seek out information that challenges their assumptions, the datasets they assemble might help correct for the bias that exists in machine learning today. News deployed as a service includes different kinds of artifacts: news stories, APIs, databases, calendar plug-ins for upcoming news events, systems that automatically generate reports using the news organization's archives, and more. As those tools are transferred from the newsroom to the business side, however, the risk of losing journalistic ethics rises, threatening to tarnish an entire organization's reputation.

EMERGING PLAYERS

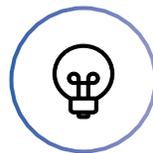
- CalMatters
- The Information
- Skift
- MIT Media Lab
- ProPublica
- The Markup

How these trends impact your company



STRATEGY

Emerging technologies present both strategic challenges as well as opportunities for growth. As the subscription economy emerges and the economy transitions away from traditional ownership models, there is more competition for share of wallet. Without entrepreneurial thinking and serious business model innovation, news organizations could find their long-term survivability at risk. Chief strategy officers and their teams should develop scenarios to forecast alternative models for growth.



INNOVATION

In what ways might AI solutions unlock new opportunities for innovation in newsrooms? How might natural language generation lead to news products that meet consumers where they are, every time they want to be informed? As we transition from Web 2.0 to Web 3.0, how should innovation teams harness emerging technologies? Companies that invest in innovation could help disrupt current models and lead to sustainable journalism. Innovation teams can play an important role by working together with product, risk, audience development and newsroom teams on their expectations and road maps.



R & D

Media consolidation led to slashed R&D budgets. The industry as a whole has underfunded serious R&D efforts for the past decade, instead relying on external tech companies to design, test and build new systems that create and distribute content. Media organizations must prioritize meaningful R&D efforts that work on longer-time horizons. This will ensure go-to-market strategies for revenue generation, audience engagement, and partnerships—with quality journalism and trust at the epicenter of new platform and product development.



GROWTH

The transition to Web 3.0 will bring new interfaces, platforms, distribution paradigms, and opportunities for transparency. Media organizations must forecast avenues for meaningful growth knowing that the industry faces headwinds from external technology players. For organizations willing to think expansively about alternative futures, a new era of sustainable journalism is on the horizon.

Key Questions

We recommend using this report to support your strategic foresight activity in the coming year. Every executive team should begin by asking these questions:

1

- ▶ How will trust in media impact our ability to thrive as a business?

- ▶ As a community?

- ▶ As a society?

2

- ▶ How will our employees and customers find information in the future?

- ▶ How might new paradigms be used to our organization's advantage, or to our detriment?

3

- ▶ How should our organization think about subscription models?

- ▶ How does the success or failure of content monetization inform our strategy?

Selected Sources

"2021 Edelman Trust Barometer." Edelman, 16 March 2020, <https://www.edelman.com/trust/2021-trust-barometer>.

Argoub, Sabrina. "The NLP Divide: English Is Not the Only Natural Language." Polis, London School of Economics, 23 June 2021, <https://blogs.lse.ac.uk/polis/2021/06/09/the-nlp-divide-english-is-not-the-only-natural-language>.

Bloom, Jesse D. "Recovery of Deleted Deep Sequencing Data Sheds More Light on the Early Wuhan Sars-COV-2 Epidemic." *Molecular Biology and Evolution*, vol. 38, no. 12, 16 Aug. 2021, <https://doi.org/10.1101/2021.06.18.449051>.

Blythe, Jessica, et al. "Fostering Ocean Empathy through Future Scenarios." *People and Nature*, vol. 3, no. 6, 2021, pp. 1284–1296, <https://doi.org/10.1002/pan3.10253>.

Coppins, McKay. "A Secretive Hedge Fund Is Gutting Newsrooms." *The Atlantic*, 5 Nov. 2021, <https://www.theatlantic.com/magazine/archive/2021/11/alden-global-capital-killing-ameri->

[cas-newspapers/620171](https://www.cas-newspapers/620171).

Douek, Evelyn. "Governing Online Speech: From 'Posts-as-Trumps' to Proportionality and Probability." *Columbia Law Review*, vol. 121, no. 3, 2020, <https://doi.org/10.2139/ssrn.3679607>.

Edmonds, Rick. "The National Trust for Local News Is Trying to Build a \$300 Million Fund to Help Save Local News." Poynter, 15 Sept. 2021, <https://www.poynter.org/locally/2021/the-national-trust-for-local-news-is-trying-to-build-a-300-million-fund-to-help-save-local-news>.

Goodman, Matt. "The City's Investigation Into the Police Data Loss Is Damning." *D Magazine*, 4 Oct. 2021, <https://www.dmagazine.com/frontburner/2021/10/the-citys-investigation-into-the-police-data-loss-is-damning>.

"Guided Search: A New Way to Find What You're Looking For." Pinterest Newsroom, 24 April 2014, <https://newsroom.pinterest.com/en/post/guided-search-a-new-way-to-find-what-youre-looking-for>.

Guo, Eileen. "How YouTube's Rules Are Used to Silence Human Rights Activists." *MIT Technology Review*, 29 June 2021, <https://www.technologyreview.com/2021/06/24/1027048/youtube-xinjiang-censorship-human-rights-atajurt>.

Hao, Karen. "How Facebook and Google Fund Global Misinformation." *MIT Technology Review*, 21 Nov. 2021, <https://www.technologyreview.com/2021/11/20/1039076/facebook-google-disinformation-clickbait>.

"Internet Shutdowns." *The Current*, Google, <https://iigsaw.google.com/the-current/shutdown>.

Johnson, Joseph. "Global Voice Search Region Device 2019." *Statista*, 27 Jan. 2021, <https://www.statista.com/statistics/1036727/global-voice-search-region-device>.

Krouse, Sarah. "Google Search Wants to Curate Big News. It Could Be a Minefield." *The Information*, 8 Oct. 2021, [\[to-curate-big-news-it-could-be-a-minefield?shared=0e5d70dbab8370d-d&rc=lxgfh\]\(https://www.theinformation.com/articles/google-search-wants-to-curate-big-news-it-could-be-a-minefield?shared=0e5d70dbab8370d-d&rc=lxgfh\).](https://www.theinformation.com/articles/google-search-wants-</p>
</div>
<div data-bbox=)

"Lockdown Fuels 'Subscription Society' as Brits Spend £552 a Year on Sign-up Services." *Barclaycard*, 2021, <https://home.barclaycard/press-releases/2020/8/Lockdown-fuels-Subscription-Society>.

Media Literacy in Finland. Ministry of Education and Culture, 24 Feb. 2021, <https://medialukutaitosuomessa.fi/en/category/medialukutaito/>.

"Media Literacy Index 2021." *Open Society Institute*, 14 March 2021, <https://osis.bg/?p=3750&lang=en>.

Metzler, Donald, et al. "Rethinking Search: Making Domain Experts out of Dilettantes." *ACM SIGIR Forum*, vol. 55, no. 1, 21 July 2021, pp. 1–27, <https://doi.org/10.1145/3476415.3476428>.

Newton, Casey. "What I Learned From a Year on Substack." *Platformer*, 17 Sept. 2021, [\[stack\]\(https://www.platformer.news/p/what-i-learned-from-a-year-on-substack\).](https://www.platformer.news/p/what-i-learned-from-a-year-on-sub-</p>
</div>
<div data-bbox=)

"Over 37.000 Deltok I Digitalt 17. Mai-Tog På Minecraft." *Aftenposten*, 18 May 2021, <https://www.aftenposten.no/norge/i/WOwlwr/over-37000-deltok-i-digitalt-17-mai-tog-paa-minecraft>.

Pisapia, Amelia, et al. "Prioritizing Human Perspectives in Natural Language Processing." *The New York Times*, 21 Dec. 2020, <https://rd.nytimes.com/projects/prioritizing-human-perspectives-in-natural-language-processing>.

Reuters. "Natural Language Processing Tech Startup Primer Raises \$110M." *VentureBeat*, 24 June 2021, <https://venturebeat.com/2021/06/23/natural-language-processing-tech-startup-primer-raises-110m>.

Ryan, Aidan. "Startups Bank on Artificial Intelligence to Help Fill News Deserts." *The Information*, 24 June 2021, <https://www.theinformation.com/articles/startups-bank-on-artificial-intelligence-to-help-fill-news-deserts?rc=lxgfh>.

Selected Sources

Smith, Ben, and Katie Robertson. "Ozy Media Is Accused in a Lawsuit of 'Fraudulent Conduct.'" *The New York Times*, 5 Oct. 2021, <https://www.nytimes.com/2021/10/05/business/ozy-media-securities-fraud-lawsuit.html>.

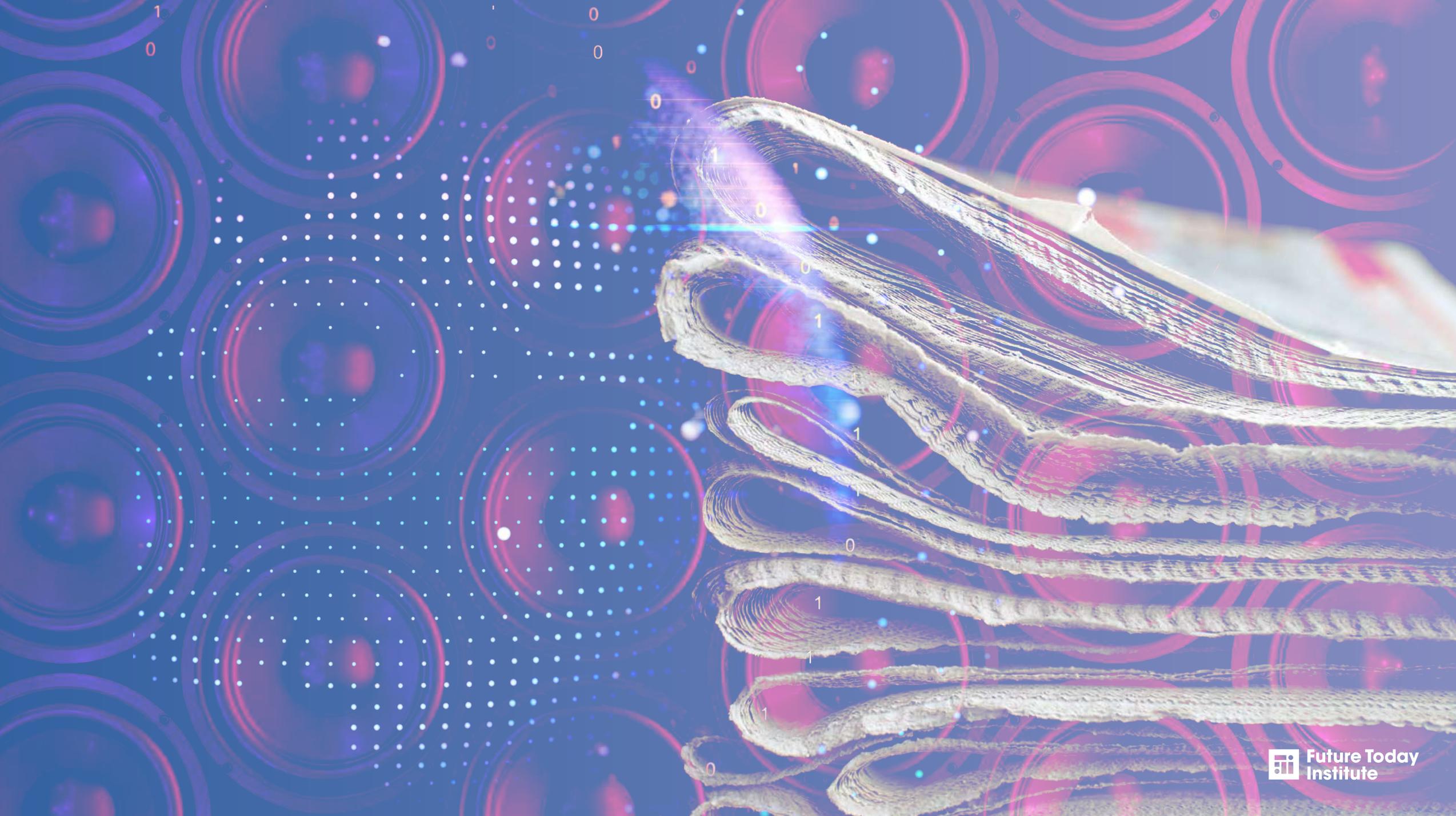
"Suggested Language List." Prevention, Advocacy & Resource Center, Brandeis University, Aug. 2021, <https://sites.google.com/brandeis.edu/parcsuggested-languagelist/categories>.

Sutcliffe, Chris. "NDC Mediagroep's Ard Boer and United Robots' Cecilia Campbell on How Robot Journalism Is Powering the Modern Newsroom." *Media Voices*, 21 Sept. 2021, <https://voices.media/media-voices-conversations-robot-journalism-powering-modern-newsrooms>.

Takahashi, Dean. "NY Mayoral Candidate Andrew Yang Joins the Metaverse with a Zepeto Avatar." *VentureBeat*, 11 June 2021, <https://venturebeat.com/2021/06/11/ny-mayoral-candidate-andrew-yang-joins-the-metaverse-with-a-zepeto-avatar>.

"Textless NLP: Generating Expressive Speech From Raw Audio." *Meta AI, Meta*, 9 Sept. 2021, <https://ai.facebook.com/blog/textless-nlp-generating-expressive-speech-from-raw-audio>.

Tian, Feng, et al. "Emotional Arousal in 2D versus 3D Virtual Reality Environments." *PLOS ONE*, vol. 16, no. 9, 2021, <https://doi.org/10.1371/journal.pone.0256211>.



Health & Medicine

Tech and science trends influencing the future of health care, medicine, and pharmaceuticals.

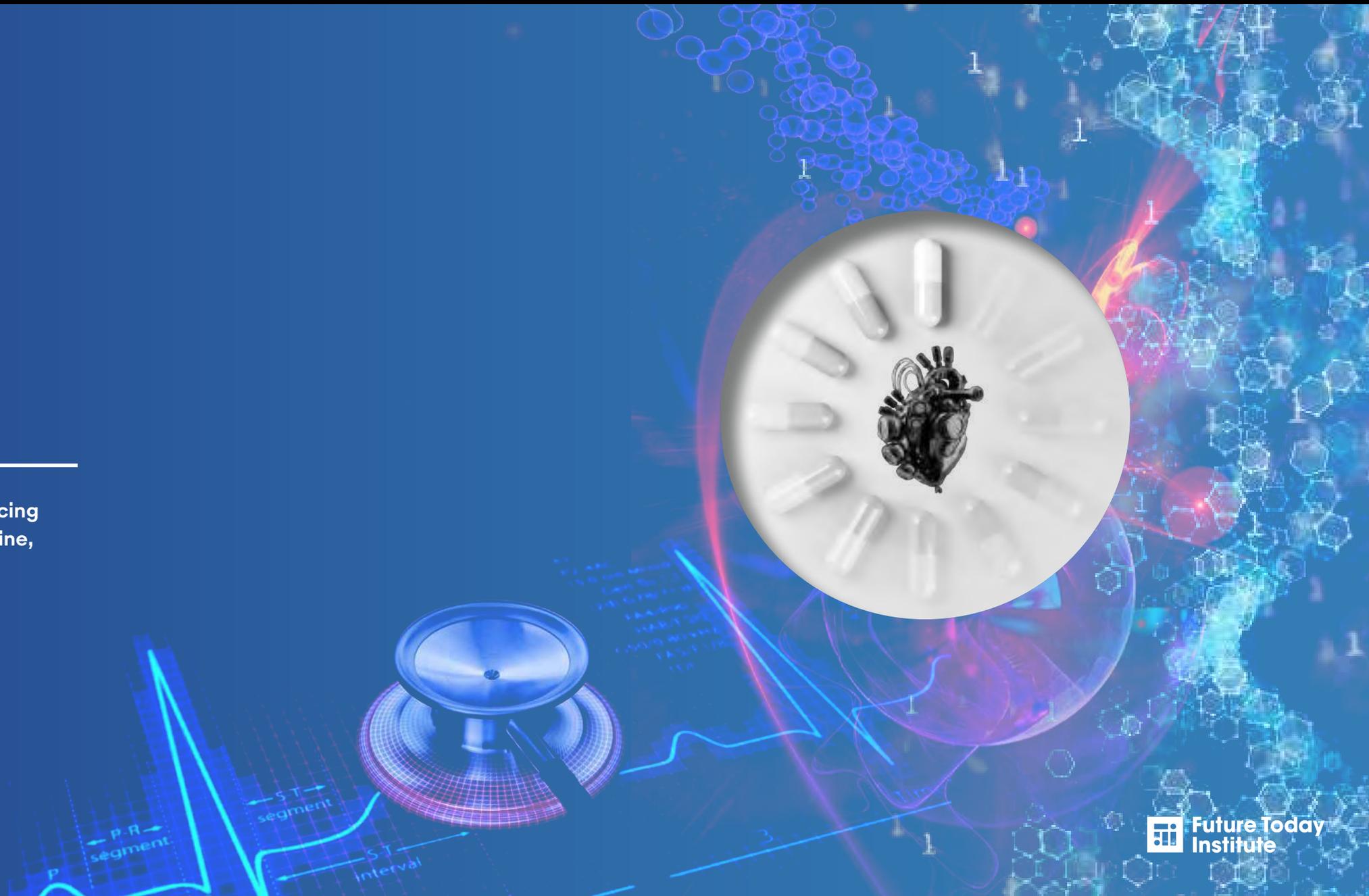


Table of Contents

270 Key Insights	293 Illness-Detecting Sensors	300 Application
271 Chief Health Officers	293 Adaptive and Assistive Wearables	301 Key Questions
272 Doctorless Exams	293 Touch-Sensitive Materials	302 Selected Sources
273 At-Home Medical Laboratory Tests	294 Tattoos and Electronic Skins	
274 Telemedicine	294 Dissolving Bioelectronics	
275 Direct-to-Consumer Health Care Models	294 Nanobots	
276 Big Tech Disrupts Health Care	295 Smart Threads	
278 Amazon's Health Care Ambitions	295 Connected Fabrics and Apparel	
279 Prescription-Strength Gaming	296 Emerging Wearables	
280 Medical Misinformation and Disinformation	296 Cloud-Based Wireless Body Area Networks	
281 Medical Extended Reality	296 Smart Biohazard Wearables	
282 Brain Machine Interfaces	296 Commercial Full-Body Exoskeletons	
283 Scenario: Concie-Air Medical Drone Service	296 Wearable Air Conditioners	
284 Patient-Generated Health Data	296 Skinput Systems	
285 Automatic Medical Transcribing	297 Mature Wearables	
286 Remote Patient Monitoring	297 Watches	
287 Digital Fitness and Training	297 Rings and Bracelets	
288 Scenario: Personal Trainers	297 Hearables and Earables	
289 Cognitive and Neural Optimization	298 Smart Glasses	
290 DIY Health and Wellness	298 Head-Mounted Displays	
292 Wearables and Biointerfaces	298 Smart Shoes	
293 Next Generation Diagnostics and Treatments	298 Smart Gloves	
	299 Scenario: An Offer You Can't Refuse	

Key Insights

- * Big Tech is doubling down on its bet to disrupt the healthcare industry, while also reorganizing and shifting strategies.
- * Membership-based services and health tech startups are creating new models that better fit the needs and lifestyles of younger, digitally savvy generations.
- * Telemedicine is becoming more full-service, with startups expanding into new areas of care.
- * Technology is bringing the power of the laboratory into our homes.
- * Breakthroughs in sensors and artificial intelligence are expanding the possibilities for remote diagnosis.
- * Because of its scale and reach, Amazon could force established pharmaceutical companies, health care systems, and insurers to adapt and evolve.
- * Therapeutic games generate detailed patient data, and algorithms can automatically adjust treatment, ultimately lowering costs.
- * Beyond patient care, augmented reality and virtual reality are being used to train surgeons and provide real-time surgical guidance. The technology could disrupt medical education and expand the capabilities of telemedicine.
- * Remote patient monitoring will help patients stay in their homes and cut medical costs.

2ND YEAR ON THE LIST

Chief Health Officers



In late 2020, Tyson Foods appointed Dr. Claudia Coplein as its first-ever chief medical officer.

KEY INSIGHT

Once limited to pharmaceutical companies, hospitals systems, and insurance providers, chief health officers and chief medical officers are getting recruited to all sorts of companies that need the role to guide decisions during the global health crisis. Job descriptions are expanding beyond pandemic protocols and remote work policies to include other aspects of employee wellness, such as mental health.

EXAMPLES

Delta Air Lines and Royal Caribbean Cruises quickly created CHO and CMO roles during the pandemic, followed by less obvious companies that needed the position. Constellation Brands, a beer and wine maker, and Tyson Foods added in-house medical expertise in late 2020. Salesforce built on its 2018 hiring of Ashwini Zenooz as the company's first chief medical officer long before the pandemic to release its Vaccine Cloud, which lets customers manage and schedule COVID vaccines, in early 2021. Last July, Midwestern supermarket chain Hy-Vee hired Dr. Daniel Fick to be its first chief medical officer, and retailer Dollar General named Dr. Albert Wu as its first CMO when it rolled out prescription drug and telehealth services.

DISRUPTIVE IMPACT

Beyond the pandemic, CHOs look holistically at employee and customer wellness. Healthy and safe people are more productive—and as consumers, they potentially spend more on products and services. Colleges and universities are also starting to add CHOs to executive cabinets to develop policies and strategies that promote health and wellness for students, faculty, and staff. In June 2021, Indiana University appointed its first chief health officer, joining a number of other schools, including the University of Michigan and Bowling Green State University.

EMERGING PLAYERS

- Hy-Vee
- Indiana University
- Dollar General
- Constellation Brands
- Tyson Foods
- Woolworths

2ND YEAR ON THE LIST

Doctorless Exams



Biofourmis' BiovitalsHF algorithm adjusts heart failure medications for patients.

KEY INSIGHT

Breakthroughs in sensors and artificial intelligence are expanding the possibilities for remote diagnosis. Data captured by clinical-grade sensors is triaged by algorithms, reducing the time from insights to action.

EXAMPLES

AliveCor's personal EKG devices now calculate cardiac QT interval, an early risk indicator for life-threatening arrhythmias. Last July, the Food and Drug Administration granted a "breakthrough device designation" for a wearable device called BiovitalHF for heart failure patients. Made by Boston health technology company Biofourmis, it combines patient-reported symptoms and lab results to automatically adjust medications. Apple added the "walking steadiness score" to its iPhone and Apple Watch, which warns if someone might fall. Rockley Photonics of Pasadena, California, recently unveiled its "clinic on the wrist." It's a wearable that uses infrared spectrophotometers to measure traditional vitals like temperature and blood pressure, and to detect hydration, muscle lactate, alcohol, and glucose levels. Rockley's largest customer is Apple, so the Apple Watch may soon monitor even more aspects of wellness.

DISRUPTIVE IMPACT

By detecting health changes before symptoms are felt, continuous health monitoring can cut intervention costs and improve outcomes. Insurers, including Blue Cross Blue Shield and UnitedHealthcare, have started offering free or discounted devices for their members. As algorithms improve, we'll see more accurate risk predictions and close the gap in care. The future is not entirely optimistic, however. We are already seeing examples of bias in medical algorithms exacerbating inequities in care.

EMERGING PLAYERS

- Sonde Health
- Ellipsis Health
- AliveCor
- Biofourmis
- Apple
- Butterfly Network
- VitalFlo
- Rockley Photonics

2ND YEAR ON THE LIST

At-Home Medical Laboratory Tests



Rapid COVID-19 test kits accelerated in-home laboratory testing.

KEY INSIGHT

Technology is bringing the power of the laboratory into our homes. Smart toilets and mirrors will turn everyday routines into opportunities to detect early warning signs of illness. Health monitoring and testing will be seamlessly integrated into our daily lives.

EXAMPLES

COVID-19 fueled at-home collection and new platforms that can accurately detect viral infection from throat and nose swabs in less than 30 minutes. Early COVID tests required samples to be shipped to a lab, but in April 2021, the FDA approved home test kits by Cue Health that processed samples and sent test results directly to apps for patient review. Lucira had been working on an at-home flu test, but in 2020 it pivoted to focus on COVID. OutSense uses sensors in toilets to screen for dehydration, infection, and traces of blood. Similarly, Coprata, a startup spun out of Duke University, uses a fingerprint scanner on the toilet handle to track each individual's health in multi-person households.

DISRUPTIVE IMPACT

The National Institutes of Health created the Rapid Acceleration of Diagnostics initiative during the pandemic to accelerate commercialization of testing technologies. The NIH expects the changes to lower the cost of diagnostic testing and expand accessibility for at-home testing. Expanding capabilities and product offerings will disrupt clinical laboratory networks like Labcorp and Quest Diagnostics and eventually impact traditional primary care providers.

EMERGING PLAYERS

- Cue Health
- OutSense
- Coprata
- Lucira
- Healthy.io
- Toto

2ND YEAR ON THE LIST

Telemedicine



Telemedicine should improve affordability and access to health care.

KEY INSIGHT

Telemedicine took off during the pandemic, but emergency orders that expanded access are expiring, leaving many patients without access to their out-of-state providers. Telehealth usage dropped far below the April 2020 peak, yet remains well above pre-pandemic levels, while investment in telehealth startups is reaching record highs.

EXAMPLES

Telehealth accounted for almost 30% of \$19 billion in digital health investments made during the first half of 2021. That doesn't include internal corporate investments made by nontraditional players like Amazon, which announced a national expansion of its Amazon Care telehealth services, and Walmart, which acquired telehealth provider MeMD and plans to provide health care in a total of 37 states. Investors injected \$5.4 million into Juno Medical's plans to expand its virtual services nationwide by 2022. Telehealth startup Spora Health provides "culture-centered care" to better meet the needs of people of color and reduce racial inequities in health care. Hospitals are using telemedicine to tap into the expertise of external specialists—during the pandemic, hospitals with tele-ICU services reduced transfers of COVID patients to larger hospitals for specialized care.

DISRUPTIVE IMPACT

Telemedicine is becoming more full-service, with startups expanding into new areas of care. New York City-based Ro started in 2017 as a discreet solution for erectile dysfunction and hair loss, but it has since expanded to provide telemedicine, pharmacy distribution, and an in-home care network for blood draws and vaccinations. The \$5 billion company now plans to support remote monitoring of chronic conditions. Full-service telehealth threatens the long-term survival of traditional primary care providers—especially with AI that can triage patients. Telemedicine also lets smaller, rural hospitals coordinate care with outside specialists. Whether a growth opportunity or a disruptive external force, telemedicine is here to stay, and as its capabilities expand, it will likely impact more aspects of our health system.

EMERGING PLAYERS

- Spora Health
- Amazon Care
- Noom
- Accolade
- Cerebral
- K Health
- Sesame
- Carbon Health
- Hims & Hers Health
- The Pill Club
- Maven Clinic
- Candlelit Therapy
- Headspace Health
- Ro
- 98point6

2ND YEAR ON THE LIST

Direct-to-Consumer Health Care Models



KEY INSIGHT

Membership-based services and health tech startups are creating new models that better fit the needs and lifestyles of younger, digitally savvy generations.

Subscription-based health care providers like Forward monitor members from home and market 24/7 access to a care team.

Credit: Forward

EXAMPLES

San Francisco-based Forward, buoyed by \$225 million from investors, will expand nationwide with its preventive health care memberships that use technologies to remotely diagnose and treat patients. Initial visits include biometric body scanning, a blood panel, genetic analysis, skin screening, and a mental health assessment. Similarly, concierge medical provider One Medical offers 24/7 access to virtual care and uses connected devices and wearables to manage existing conditions. Canadian company Tia Health specializes in women's health and offers unlimited messaging and same-day appointments. Sweetch is a startup that uses AI to manage chronic conditions by timing personalized interventions to boost your likelihood of responding.

DISRUPTIVE IMPACT

This next generation of care relies on home diagnostics, self-monitoring, and telemedicine. As more consumers seek out convenient, on-demand health care, the tech-enabled services will threaten traditional primary care models.

EMERGING PLAYERS

- Forward
- Tia Health
- Higi
- mPort
- Crossover Health

4TH YEAR ON THE LIST

Big Tech Disrupts Health Care



Amazon Pharmacy launched six-month \$6 generic prescriptions in 2021.

Credit: Amazon/Reuters

KEY INSIGHT

Big Tech is doubling down on its bet to disrupt the health care industry, while also reorganizing and shifting strategies.

EXAMPLES

Google is narrowing its focus to clinical tools and research—and culling data from its health cloud deals and Fitbit users. It dismantled its Google Health division in August 2021, integrating its health efforts across myriad business units, and ended support for its clinical support app Streams. Amazon is expanding its rebranded cloud service AWS for Health to attract health care partners and is disrupting the medical supply chain with its \$6 generic drug program and by signing up more employers for its virtual-first Amazon Care service.

Apple is rolling out new health features to the Apple Watch, which by 2022 will measure blood pressure and support temperature-based fertility planning. Its iOS 15 enables people to share health information with family and providers, and lets them know about changes in

health trends. Collaborative research studies with large health institutions are using real-world data from Apple devices to identify early warnings of health problems. This research has led to new features that alert users to take action; the walking steadiness score assesses balance, stability, and coordination through built-in motion sensors and warns of fall risks. The company is working with researchers at Biogen and the University of California, Los Angeles to develop an algorithm that detects mental illness biomarkers by measuring mobility, physical activity, and sleep patterns. Apple reportedly piloted its own subscription health service that would integrate health data from Apple devices—but the project stalled.

Microsoft acquired AI speech recognition company Nuance Communications in April 2021—a deal that should strengthen its clinical decision support

software. Facebook is expected to unveil in 2022 its first smartwatch, which is rumored to include fitness features like a heart rate monitor.

Big Tech Disrupts Health Care



Apple continues to roll out new health features that use potential early warning signs to trigger interventions.

Credit: Apple

DISRUPTIVE IMPACT

As Big Tech continues to disrupt the U.S. health care industry, it is making inroads with data interoperability and clinical tools. If successful, the companies could collapse some silos prevalent in the industry and finally bridge the gap between individual behavior and health impacts. Cloud services open up entry for world-class AI capabilities in an industry that has long struggled to effectively use longitudinal patient data. Of all the players, Amazon is the only one jumping into delivery of services with pharmacy and primary care. (See: Amazon's Health Care Ambitions.)

EMERGING PLAYERS

- Google Cloud Healthcare Data Engine
- Dr. Amy Abernethy, president of Verily's clinical research unit
- Babak Parviz, vice president at Amazon
- Dr. Freddy Abnoui, Facebook's head of health technology



I don't think Big Tech is going away in health care, despite many of the headlines recently. Big Tech is in health care, and each player has a different lever and specialty that it can bring to care innovation.

— Missy Krasner,
Redesign Health's venture chair

Amazon's Health Care Ambitions

Amazon is health care's most ambitious disruptor. Every acquisition or new service announcement moves markets. Over the past year, Amazon struck partnerships with hospitals and insurers. Here's a look at where Amazon is investing its money and focus:

Online Pharmacy

In June 2021, Amazon Pharmacy unveiled a Prime program that lets members buy a six-month supply of many generic prescriptions for as little as \$6. The move echoes Walmart's \$4 generic program and targets common drugs that can be bought in bulk for significant discounts.

Data Analytics

Amazon Web Services (AWS) is doubling down on health care. In August, it

partnered with GE Healthcare to boost its AI-enabled diagnostic capabilities for its rebranded AWS for Health service, one more move to attract health care providers—and their data—onto its cloud. A month earlier, the company released Amazon HealthLake, which securely stores, transforms, and analyzes health data. It uses the Fast Healthcare Interoperability Resources industry standard to ensure interoperability across organizations.

Startup Accelerator

In June, AWS launched a health care accelerator—a four-week program for health care startups that want to use AWS to solve health care challenges. The first cohort included 10 startups across the remote patient monitoring, voice tech, and virtual care spaces.

Grocery Stores

Amazon added a new Just Walk Out checkout-free feature to a Bellevue,

Washington, Amazon Fresh store. This same technology is rumored to be part of a future Amazon smart fridge that can track use of grocery items. This would enable easy reordering of food while presumably making a connection between what people buy and eat with their health data.

Telemedicine

In March, Amazon said it would expand its telehealth services to employers nationwide. It has also reportedly approached insurers to include the company's virtual-first medical service Amazon Care as a covered benefit under their plans. After speculation in September that it was expanding its hybrid model to 20 cities, Amazon confirmed its expansion of in-person care options to Dallas, Chicago, Philadelphia, Boston, and Los Angeles at the HLTH 2021 conference.

Diagnostics

The pandemic also drew Amazon into the clinical laboratory diagnostics space. The company developed a COVID-19 test for its own workers and now sells those tests through a direct-to-consumer diagnostics portal. Many expect Amazon to expand into in-home testing for respiratory and sexually transmitted infections.

Health + Wellness

Halo, Amazon's health-monitoring wristband and app, can assess functional fitness using a smartphone camera and cloud-based AI. The service, Movement Health, guides users through an assessment and scores how they perform in areas like mobility and stability. The Halo app then offers a personalized set of exercises to address any weaknesses. The Halo band can also share live heart rate data with third-party exercise equipment and fitness apps using Bluetooth Low Energy. Halo View,

an updated version of Amazon's wearable, includes a blood oxygen sensor, bringing its health tracking capabilities in line with other trackers, such as the Fitbit. Amazon rolled out two new services in the fall as part of the Halo membership: Halo Fitness, an interactive fitness platform that will compete with Apple Fitness+, and Halo Nutrition, which offers personalized meal planning and a recipe library.

Bottom Line

Amazon's focus on convenience and speed poses a significant threat to traditional primary health care. It drives down costs by cutting out the middlemen and leveraging its data and logistics expertise. As Amazon expands health care services nationwide and courts insurers, it is positioned to replace many traditional providers and amass a significant trove of data that will strengthen its efforts in the health care space.

2ND YEAR ON THE LIST

Prescription-Strength Gaming



Prescription gaming may help treat mental health conditions, including COVID-19 brain fog.

KEY INSIGHT

The FDA cleared the first video game as a prescription medical treatment for attention deficit disorder in 2020, and many expected other prescription games to follow. While a number of companies are seeking FDA approval for digital therapeutics, EndeavorRx remains the only FDA-cleared prescription game, but it has had little commercial success.

EXAMPLES

Boston-based Akili Interactive received FDA approval for its prescription game, EndeavorRx, but the company is struggling to gain market traction and establish a workflow for physicians to prescribe the digital therapeutic. It conducted a clinical study with three academic medical centers to explore whether digital therapeutics could reverse cognitive decline among COVID long-haulers. Akili and Australian med-tech TALi Digital are working to get FDA clearance for TALi's Detect and Train software, which screens for and treats inattention in children. Neuroglee Therapeutics is also seeking FDA approval for its game-based therapy to treat mild cognitive impairment. Swiss developer MindMaze—valued at \$1.5 billion—uses games to rebuild strength and mobility in patients recovering from strokes and traumatic brain injuries, and has partnered with Mount Sinai's tele-neurorehabilitation program.

DISRUPTIVE IMPACT

Therapeutic games generate detailed patient data, and algorithms can automatically adjust treatment, ultimately lowering costs. They could serve as the backbone for telemedicine for people suffering from chronic illnesses, but commercialization is elusive in this area. Reimbursement will remain an issue as insurers look for more evidence of efficacy and developers work with physicians to overcome prescribing challenges inherent with digital therapeutics. With an aging global population—and more people with cognitive impairment—the sector could gain traction as companies demonstrate effectiveness in treating neurodegenerative diseases.

EMERGING PLAYERS

- Neuroglee Therapeutics
- Akili Interactive Labs
- MIT Media Lab
- MindMaze

1ST YEAR ON THE LIST

Medical Misinformation and Disinformation



Medical misinformation accelerated during the pandemic, forcing state medical boards to take action.

KEY INSIGHT

Medical misinformation and disinformation aren't new, but the pandemic dramatically deepened the problem—so much so that state medical boards are stepping in to halt the spread of misstatements from physicians.

EXAMPLES

In July 2021, the Federation of State Medical Boards' board of directors stated that doctors generating and spreading COVID-19 vaccine misinformation or disinformation risk disciplinary action, including loss of their medical license. While YouTube and Facebook have been home to many COVID falsehoods, a networking site for medical professionals, Doximity, is also experiencing a rise in conspiracy theories.

Misinformation and disinformation have grown into a revenue-generating business on social media platforms where content drives ad revenue and the audience is encouraged to purchase merchandise. The movement doesn't stop there, however. The acceleration of telemedicine improved access to health care, but it also drove traffic to sites like SpeakWithAnMD.com, which promises it can provide and fill prescriptions for "miracle cures" for COVID.

DISRUPTIVE IMPACT

For years, health and wellness realms streamed misinformation about diets, natural remedies, and vaccines, and social media platforms easily amplify these messages. Even after Facebook promised to limit the reach of anti-vax content, groups and pages still proliferate.

The problem is a global one—in Southeast Asia, efforts to remove anti-vaccination posts from social media platforms pushed groups onto the encrypted messaging platform Telegram and beyond the reach of government guidelines and regulation. The answer won't come from simply blocking content on platforms or from a surgeon general's advisory. But if solutions don't emerge to slow down the spread of misinformation and disinformation, global public health will suffer.

EMERGING PLAYERS

- Telegram
- George Washington University's Institute for Data, Democracy & Politics
- Stanford Internet Observatory
- World Health Organization
- First Draft News
- The Technology and Social Change Project at Harvard Kennedy School of Government

1ST YEAR ON THE LIST

Medical Extended Reality



Surgeons use the mixed reality of Microsoft HoloLens to visualize their approaches before and during surgery.

Credit: Microsoft

KEY INSIGHT

From treatment of mental disorders to pain management, virtual reality is gaining traction in medicine. Beyond patient care, augmented reality and virtual reality are being used to train surgeons and provide real-time surgical guidance. The technology could disrupt medical education and expand the capabilities of telemedicine.

EXAMPLES

In 2020, Johns Hopkins Medicine researchers found that VR games reduced anxiety and pain in pediatric patients during medical procedures. Boston-based Rendever will further study whether VR experiences improve quality of life for socially isolated seniors, thanks to a \$2 million grant from the National Institutes of Health. In February 2021, AppliedVR's EaseVRx—one of the first VR therapies to receive a “breakthrough device designation” from the FDA—showed “clinically meaningful” improvement in lower back pain in a randomized controlled trial. San Francisco-based Osso VR, boosted by a \$27 million Series B round, is expanding its VR surgical training and assessment platform to include additional specialties and procedures. Pixee Medical's FDA-cleared Knee+ system uses AR glasses to help surgeons judge joint alignment during knee replacements.

DISRUPTIVE IMPACT

Despite the promise, VR systems often lack randomized, controlled clinical trials. Many VR benefits have been based on small studies that lacked blinded controls.

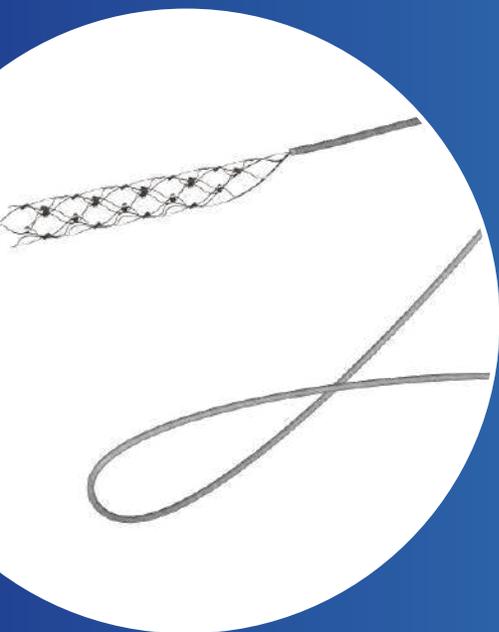
Another challenge for VR therapeutics is medical coverage: Most patients have to pay out of pocket for the therapy. Broad insurance coverage for VR therapy could be further delayed by a September 2021 decision from the Centers for Medicare & Medicaid Services to withdraw an accelerated plan for coverage under the FDA's Breakthrough Devices Program. If these challenges are overcome, VR platforms could become an important option for telemedicine and home-based care.

EMERGING PLAYERS

- Medical Virtual Reality at the USC Institute for Creative Technologies
- Cedars-Sinai's Health Services Research
- Neuro Rehab VR
- Oxford VR
- Osso VR
- AppliedVR
- FundamentalVR
- HalfDive
- TRIPP
- Microsoft HoloLens

5TH YEAR ON THE LIST

Brain Machine Interfaces



Synchron's Stentrode, an implantable brain-computer interface, won FDA approval to begin an early feasibility study in late 2021.

Credit: Synchron

KEY INSIGHT

In the first eight months of 2021, investors put \$300 million behind startups focused on brain-machine interfaces (BMI) or brain-computer interfaces (BCI)—triple the amount raised in 2019. Research has focused mainly on medical applications, but Ford and Mercedes-Benz are exploring how BCI could be used for vehicle control.

EXAMPLES

The University of Pittsburgh's Rehab Neural Engineering Labs developed two-way communication with a BCI to mimic tactile sensations, a development that could provide crucial feedback for improving the control of prosthetics. Brown University researchers are placing microscale neural sensors called neurograins on the outer layer of the brain. Synchron received FDA approval for an early feasibility study with Mount Sinai, UPMC, and Carnegie Mellon to explore a minimally invasive approach using blood vessels to implant its fully internalized Stentrode neuroprosthesis device.

DISRUPTIVE IMPACT

Facebook sponsored research at University of California, San Francisco, only to later abandon efforts to turn BCIs into wearable consumer technology. But research into consumer-facing technology isn't dead: A global collaboration led by Georgia Institute of Technology demonstrated that participants could use its wireless BMI system to accurately control virtual reality exercises. The researchers also developed a machine learning model that improved the accuracy of the system. Availability of wireless BMIs that no longer require implantation will likely expand use of BMIs. The possibility of broader use has groups raising ethical concerns: The NeuroRights Foundation seeks to establish "neuro-rights" before the technology reaches the mainstream.

EMERGING PLAYERS

- Synchron
- NextMind
- Kernel
- Neurable
- Neuralink
- NeuroPace
- Bitbrain

CONCIE+AIR

Welcome!

Your neighborhood has enrolled in our medical drone subscription service, and as a new resident, you will receive coverage through your community fees. We are excited to walk you through an overview of how we can help you.

1 Our drones are trained to listen for screams and other signs of distress. Once detected, an EMT drone will deploy to your location and assess the situation within 45 seconds. You can speak directly to the drone—its advanced voice capabilities are equipped to understand the top 10 global languages, even when the speaker is distressed.

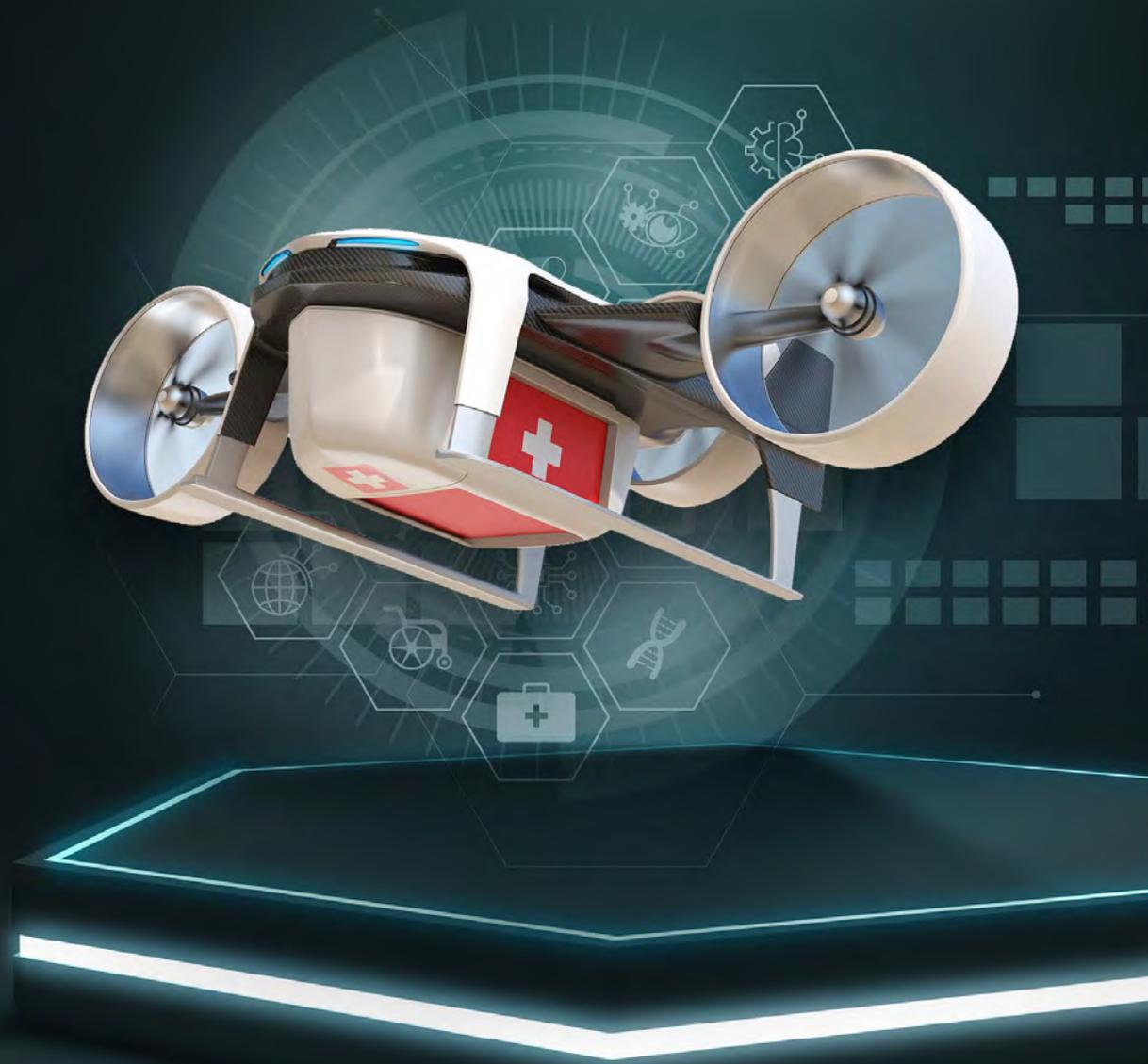
2 The EMT drone will scan the area and your current physical condition. It can detect heart rate, respiration, and blood pressure through radio waves. Any wearables you may have will be detected and may receive an emergency access request to link to their data streams.

3 Our EMT drone may ask you to demonstrate movement of limbs and inquire about the events leading up to the incident. The more information you provide, the more comprehensive we can be in our response.

4 If you are unable to answer, our EMT drones are equipped with AEDs to restore a normal sinus heart rhythm, and they can perform CPR as needed. Our specialized trauma swarms are certified to apply tourniquets, stabilize broken bones, and place C collars. Some minor stitching can be performed on-site as well.

5 In some of the remote areas we cover or when barriers prevent access, our transport drones can be deployed to safely take you to the nearest hospital.

While we hope life in your new community is accident-free, you can trust that if ever you need us, we will be there!



4TH YEAR ON THE LIST

Patient-Generated Health Data



APIs integrate data from wearables and medical-grade consumer devices into electronic health records.

Credit: Withings

KEY INSIGHT

With the proliferation of wearables and sensor technology comes a flood of patient data that can help health care providers assess a person's overall health. But capturing that data in electronic health record (EHR) systems and making use of it in a clinical setting has challenged an industry that lags in digital transformation.

EXAMPLES

Hundreds of devices collect and monitor patient health data, but health care systems have struggled to integrate that data into EHR systems. The result: a new market for businesses focused on interoperability. The Fast Healthcare Interoperability Resources (FHIR) standards for APIs connect data from smart devices and platforms, including Apple HealthKit to EHRs. Withings, a maker of smart scales and connected devices, and Redox, a health IT company, are working to make Withings' Med Pro Care-connected health devices compatible with major EHR systems. In South Korea, a major digitization project involves creating a single app for patients to access their entire health record. By 2023, that same effort will integrate data from wearables and medical devices.

DISRUPTIVE IMPACT

As consumer devices inch closer to medical-grade and more connected devices are used to manage chronic disease, integration of that data into EHR systems will become a bigger focus. The ability to integrate patient-generated data into EHR systems and clinical workflows will be critical for the success of remote monitoring and telemedicine services.

EMERGING PLAYERS

- Apple Health
- Epic
- Cerner
- Validic
- Salesforce
- Google Health
- Meditech
- Allscripts
- eClinicalWorks

3RD YEAR ON THE LIST

Automatic Medical Transcribing



Nuance's health care speech-recognition capabilities reduce a key physician burden.

Credit: Nuance

KEY INSIGHT

Automatic medical transcription continued to gain traction as telemedicine accelerated during the pandemic. Transcribing clinical notes requires excellent sound quality and an understanding of medical terminology, which has been a roadblock for its adoption. Advances in artificial intelligence are improving accuracy and speed as well as providing real-time diagnostic analysis and physician alerts.

EXAMPLES

In April 2021, Microsoft announced it would acquire voice recognition software provider Nuance Communications—a move that positioned the tech giant to boost its health care cloud services. Nuance's integrations into such EHR systems as Epic and Cerner allow providers to dictate notes, use their voice to navigate EHR systems, and ultimately reduce the time it takes to provide reports to patients. By using automatic transcription in telehealth visits, providers can worry less about note-taking and focus more on the patient, while picking up on small cues that might otherwise be difficult to detect.

DISRUPTIVE IMPACT

As accuracy improves, automatic transcription can reduce the documentation burden for providers and potentially stave off burnout. Machine learning could also provide suggestions or alerts to doctors, based on the conversation's context. Clinical notes increasingly provide datasets for AI training, so improved accuracy may lead to better diagnostic algorithms.

EMERGING PLAYERS

- Amazon Transcribe Medical
- Amazon Comprehend Medical
- Microsoft/Nuance Dragon Ambient eXperience
- Nvidia BioMegatron

2ND YEAR ON THE LIST

Remote Patient Monitoring



Hinge Health's app and sensors enable in-home personalized physical therapy.

KEY INSIGHT

The pandemic accelerated use of remote patient monitoring (RPM), as health systems used it to reduce demand for hospital beds and remotely monitor COVID-19 patients at risk for developing severe disease. As the global population ages, this technology will make it safer for elderly patients to remain in their homes.

EXAMPLES

The Department of Veterans Affairs will spend \$1 billion to expand its home-based connected care, and the Centers for Medicare & Medicaid Services may expand coverage for remote monitoring, easing reimbursement challenges for the technology. Researchers are making advances in the technology's capabilities: The University of Alberta created a patch-type wearable called the ADAMM-RSM that could warn of an asthma attack and offer personalized treatment away from the doctor's office. If successful, it could be used for other respiratory diseases. Verily's Onduo will use Fitbits to manage such chronic conditions as diabetes and hypertension. Carbon Health acquired Alertive Healthcare, a remote monitoring startup, to strengthen its home-based chronic care management and preventive diagnostics.

DISRUPTIVE IMPACT

RPM should help patients stay in their homes and cut medical costs. As the technology improves, more health systems will explore "hospital-at-home" systems that can reduce the need for patients to recover at the hospital. Broad adoption continues to be slow, but investment in the area is growing. We will likely continue to see a fragmented field of service providers, though telehealth players are starting to acquire capabilities through smaller players.

EMERGING PLAYERS

- Carbon Health
- Swift Medical
- Ejenta
- Neteera
- VitalConnect
- iRhythm Technologies
- 100Plus
- Kaia Health
- Hinge Health
- Cardiac Insight

7TH YEAR ON THE LIST

Digital Fitness and Training



Tempo uses 3D sensors and AI to analyze form and provide real-time feedback.

Credit: Tempo

KEY INSIGHT

Digital fitness companies like Peloton experienced 400% to 500% growth in 2020 but that growth has significantly slowed. With rising competition, we will likely see consolidation in the area. Continued investment in the area means rising competition, and we are starting to see some consolidation.

EXAMPLES

Digital fitness players are rolling out new offerings with hopes of sustaining pandemic subscription levels. Smart gym company Tonal added live classes that provide real-time feedback and a “social zone” where users can interact with each other. Apple Fitness+ also rolled out SharePlay, which allows users to work out “together” even when miles apart. Peloton and Apple have both expanded into employer programs; both companies inked partnerships with UnitedHealth that gives the insurer’s members access to their apps for free. Investments have also flowed into the sector: Investors put \$200 million behind Whoop, which provides biometric-driven personal coaching; \$200 million behind Hydrow, a connected rowing company; and \$220 million into Tempo, which uses 3D sensors and AI to provide real-time feedback.

DISRUPTIVE IMPACT

As the in-home fitness industry scrambles to maintain subscriptions, some companies are tapping employer and insurer wellness programs to offer free access, while others are starting to expand into hospitality, by offering connected equipment in hotels for business travelers. Traditional gyms and fitness centers, meanwhile, will be forced to upgrade equipment and offerings to stay competitive and relevant in the personalized fitness world.

EMERGING PLAYERS

- Peloton
- Apple Fitness+
- Tonal
- Lululemon’s Mirror
- Ergatta
- Zwift
- Wahoo Fitness
- CLMBR
- Hydrow
- Tempo
- NordicTrack Vault

Personal Trainers

Soft robotics allowed at-home fitness to become far more interactive. At first, smart fabrics embedded into fully flexible sleeves made it so post-op and injured patients could receive physical therapy remotely. Soon, the tech also became a hit with smart gym companies. Wearable robotics that could sense and adjust in real time to correct movement patterns became incorporated into many home gym's on-demand and live fitness classes. As a premium feature, clothes could nudge a person into the right position or adjust the resistance for "weight."

But few people realized that the clothing also captured advanced biometric data, including the amount

of effort exerted and a participant's emotions during a workout. This information fed the rise of synthetic media fitness trainers. These hyper-personalized trainers provide "hands-on" attention during the class—no matter how large—and then ultimately lock in members to the platform on an emotional level. People brag about finding their all-time favorite trainer—not realizing that every interaction was specifically molded to their exact responses and preferences. Fitness fanatics don't catch on that "their" Cody—while maybe sharing a common personality base—had evolved into something completely different. Literally a personal trainer.



2ND YEAR ON THE LIST

Cognitive and Neural Optimization



Recollect, one the brain-training games out of University of California's Riverside Brain Game Center, is designed to improve memory.

Credit: UC Riverside Brain Game Center

KEY INSIGHT

Brain training is a controversial multibillion-dollar industry. These interventions have had inconsistent results in research studies, and their real-life performance remains largely subjective. The industry is fueled by the emerging long-term cognitive impacts of COVID-19 and an aging population facing cognitive decline.

EXAMPLES

Cognitive sports trainer Reflexion partnered with esports league Evil Geniuses to build a visual cognitive training program for esports athletes that is designed to improve peripheral vision, decision-making, reaction time, and hand-eye coordination. The National Institutes of Health is funding research in cognitive enhancement, including an Alzheimer's study at the University of South Florida that will explore whether computerized games can reduce the risk of cognitive decline in aging adults. Researchers at the University of California, Riverside and the University of California, Irvine are looking at the gamification and personalization of memory training, driven by the theory that previous studies showed inconsistencies because of neural differences. Individualization, then, could improve results.

DISRUPTIVE IMPACT

While cognitive interventions may show improvements in the games themselves, translating those performance gains in real-world applications has been inconsistent. That has not slowed research in the area given the needs of an aging global population. Even athletes are looking at how these games can improve cognitive performance and create a competitive edge. As use of the technology grows and NIH-funded studies add more evidence to the discussion, we may see calls for regulation.

EMERGING PLAYERS

- UC Riverside Brain Game Center
- Reflexion
- Bitbrain
- Flow Neuroscience
- Happify
- PNOË

1ST YEAR ON THE LIST

DIY Health and Wellness



Zoe uses continuous glucose monitor data to understand how individuals respond to various foods.

Credit: Zoe

KEY INSIGHT

Wellness is a top priority for consumers. The market is growing with advances in affordable at-home genetic testing and diagnostics that analyze our microbiomes and blood levels for insights.

EXAMPLES

Humanity, backed by \$5 million from investors, aims to slow aging. The app's algorithms use data from smartphones and wearables to calculate your rate of aging and recommend changes to extend your lifespan. Personalized nutrition startup Zoe claims to learn how participants' bodies respond to different foods based on results from a home testing kit that analyzes microbiome and blood biomarker changes. Menlo Park, California-based January offers subscriptions for personalized nutrition advice based on findings from heart rate and continuous glucose monitoring. Beyond the gut, cosmetic brands like Dr. Elsa Jungman provide product recommendations based on swabs of your skin microbiome. Targeting athletes, PNOE analyzes biomarkers in the breath to measure fitness and metabolism with "clinical-grade accuracy."

DISRUPTIVE IMPACT

While consumer wellness technology expands, much of the science lags. The National Institutes of Health is investing \$160 million in precision nutrition. Its program will study interactions between diet, gut microbiome, genes, and metabolism, to generate a significant dataset that could provide supporting evidence or disprove health claims in this emerging industry. Studies like this may also lead to calls for stricter regulation. In the U.K., the country's Science and Technology Committee has already urged greater regulation of direct-to-consumer genetic testing and premarket assessments of each test's clinical performance against its claims.

EMERGING PLAYERS

- Humanity
- Zoe
- January AI
- Gainful
- Sanome
- Viome
- DayTwo
- Evvy
- Ultrahuman



Give people options, give people multiple pathways to engage care the way they want, and guess what they'll do? They'll get care.

— Marcus Osborne, Walmart Health's senior vice president.



10TH YEAR ON THE LIST

Wearables and Biointerfaces



In April, Sony started selling a more powerful wearable air conditioner called the Reon Pocket 2 in Japan.

KEY INSIGHT

We are seeing incredible growth in wearables, with more than 1,000 wearable sensors on the market—from smartwatches to advanced fabrics and materials. Viable implantable technology is beginning to emerge, and new advances may help detect and track biomarkers, and improve our health and enhance healing.

EXAMPLES

More wearables can now report data and adjust settings—independently of a smartphone or computer. Capabilities go beyond the smartwatch to include clinical-grade health monitors and full-body exoskeletons that can enhance the wearer with super-human strength. As wearables transition to implantables, we will gain greater visibility into real-time biological health.

DISRUPTIVE IMPACT

Global shipments of wearables surpassed 444 million units in 2020, up 28.4% from the prior year, according to Statista. Wearables will not only offer more data in areas where we previously had little visibility, but it will change how consumers interact with businesses and communities as they utilize new interfaces in entirely new contexts. Companies may gain greater understanding of a consumer's health, potentially without the person even knowing, and utilize it to target products and services.

EMERGING PLAYERS

- University of Texas at Austin
- Rogers Research Group at Northwestern University
- ETH Zurich
- MIT's Computer Science and Artificial Intelligence Laboratory
- Bionaut Labs
- Samsung Advanced Institute of Technology

Next Generation Diagnostics and Treatments



New mouthguards can detect specific biomarkers in saliva, which indicate inflammation or disease; they can also determine whether an athlete has likely suffered a concussion.

■ Illness-Detecting Sensors

Several 2020 studies found that wearables, such as the Oura Ring, Fitbit, and Apple Watch, can detect early signs of infections. Apple and the University of Washington used the Apple Watch to monitor changes in participants' heart rate and blood oxygenation as a potential predictor of infection. In a separate Warrior Watch Study, researchers found heart rate variability detected on Apple Watches pinpointed early signs of COVID-19. A study led by Duke University found that a wristband that monitors heart rate, skin temperature, activity, and electrodermal activity could predict viral infection and the severity of illness. The Army is using the same wristband to detect COVID. More study is needed to test the system in a more diverse population, but the findings could enable valuable public health surveillance—and provide a nice heads-up that you're coming down with something.

Scientists at Massachusetts Institute of Technology developed a robotic nose that uses biological smell receptors to detect disease by interpreting patterns of molecules, much like a dog does. Nano-Nose identifies patterns in receptor electrical activity and uses machine learning to link these patterns to disease predictions. The bot has identified prostate cancer via smell with 70% accuracy. Andreas Merzhin, one of the researchers, predicts the technology will be available in our devices within five years.

■ Adaptive and Assistive Wearables

Researchers at the University of Waterloo in Canada are using computer vision and deep learning to create more natural movement for disabled exoskeleton wearers. The ExoNet system automatically adjusts the exoskeleton's motion to

mimic the various ways humans adjust their gait to navigate surroundings like descending stairs or opening doors. The functionality eliminates the need to manually control motion through apps or joysticks. Further research will explore improving the assistive wearable's energy efficiency by using motion to charge the batteries.

■ Touch-Sensitive Materials

China's Southeast University developed a material that can respond to pressure or stretching, through liquid metal circuits and liquid crystal elastomers. The team demonstrated how the same material can change shape with temperature. The material could be used in soft robotics that sense and respond to their surroundings. National University of Singapore researchers created AiFoam, a smart foam designed to sense touch or the proximity of nearby objects. The material could help robotics quickly

Next Generation Diagnostics and Treatments

respond to dynamic environments, such as crowded areas. The foam can also self-heal and restore function after mechanical damage.

■ Tattoos and Electronic Skins

The University of Texas at Austin is exploring how graphene electronic tattoos can measure brain waves, heart activity, and muscle activity through biopotentials. Researchers received a National Science Foundation grant for work with Georgia Institute of Technology to develop an e-tattoo that remotely monitors pneumonia patients and predicts changes in their condition. A clinical trial at Texas Children's Hospital will test the e-tattoo's capability to individualize patient care and trigger early interventions before a patient's health deteriorates.

At Northwestern University, researchers are investigating soft, flexible skin-inspired electronics called electronic skins or e-skins. They created a device

for the throat that monitors speech, respiration, heart rate, and other biometrics for stroke patients, speech and physical therapy, residents of assisted living homes, and sleep monitoring. E-skins, too, are advancing. Think: thinner, more durable materials that allow people to retain a sense of touch. MIT and the Amorepacific in South Korea developed artificial sweat ducts that let sweat pass through longer-wear e-skins. Samsung Advanced Institute of Technology proved the commercial viability of stretchable e-skins that use existing semiconductor processes. These skins could be used to measure heart rate, oxygen saturation, electromyogram—or the electrical activity in muscles—and to display blood pressure data on the patch.

■ Dissolving Bioelectronics

Researchers at Northwestern and George Washington universities devel-

oped a cardiac pacing device that is absorbed by the body over five to seven weeks—ideal for postsurgical patients who may need temporary pacing. During surgery, doctors adhere the flexible device to the surface of the patient's heart. The device then harvests power from an external source using near-field communication (NFC), eliminating the need for batteries or external leads. This is the second bioresorbable device from the Northwestern lab led by John Rogers. In 2018, the team demonstrated a biodegradable implant to accelerate nerve regeneration post-op.

■ Nanobots

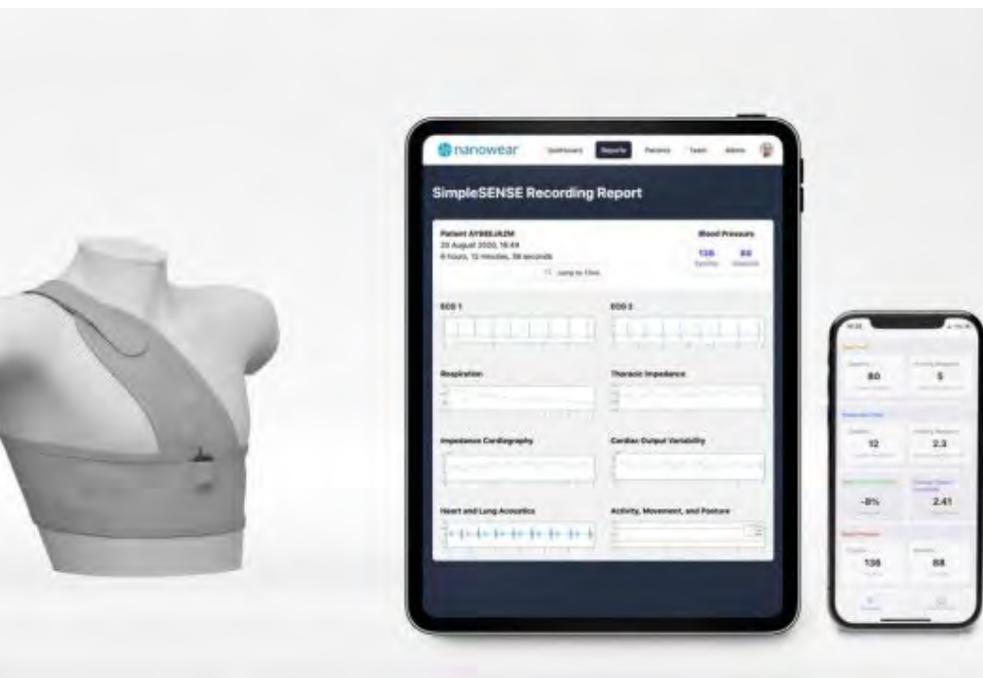
Ohio State University scientists developed software that can design more complex DNA robots and nanodevices in minutes, instead of days. Called MagicDNA, the software allows scientists to simulate operation of the bots. This could lead to more useful applications,

including detecting a programmed trigger—like a virus in the body—and responding by releasing a drug or enveloping the pathogen. It could also be used in precision drug targeting, where a drug is attached to a DNA robot using a protein linkage that is cut by an enzyme only found inside the target cell. Scientists at ETH Zurich in Switzerland are looking at how acoustic waves like ultrasound or magnetic fields can help these devices navigate to desired locations. Similarly, the European Union funded the SONOBOTS project to develop navigable nanorobotic systems for targeted drug delivery, precision microsurgery and biopsies, and diagnostics. Another EU-funded project, ANGIE, will investigate steerable nanodevices and magnetic navigation systems for localized treatment of blood clots. Up next: interventions in multiple chronic diseases.

While mainstream use of nanobots is still a ways off, Los Angeles-based start-

up Bionaut Labs received humanitarian use device designation in September 2021 from the Food and Drug Administration for its nanobot drug-device system, BNL-201, to treat Dandy Walker Syndrome, a rare pediatric neurological disorder. Bionaut plans to use the nanobots in a minimally invasive local microsurgery procedure to restore patient brain function and development. Just three months earlier, the FDA awarded the “orphan drug designation” to Bionaut's BNL-101 device, which treats malignant gliomas in the brain. Because their nanomaterials can cross the blood-brain barrier, Bionaut's bots should be able to access parts of the brain that are too risky for traditional surgery. These breakthroughs bring nanobots one step closer to human clinical trials. Despite the potential, the United Kingdom's Royal Society issued a 2021 report calling for more transparency into nanobot mechanisms and systems, in addition to mitigation of the inherent

Next Generation Diagnostics and Treatments



FDA-cleared SimpleSENSE is a cloth-based remote diagnostic platform for the heart, respiratory and upper vascular systems.

Credit: PRNewsfoto / Nanowear

risks involved in granting these devices greater autonomy in the human body.

■ Smart Threads

MIT researchers created a washable fiber that can sense, store, and process data. Using AI, the fiber could provide you with real-time alerts about potential respiratory problems or arrhythmias. MIT is working with the Army to develop the technology, which could alert the wearer of critical health data and inform support forces of injuries. Researchers at the Missouri University of Science and Technology are using smart fibers to develop a helmet that can detect real-time concussions among athletes.

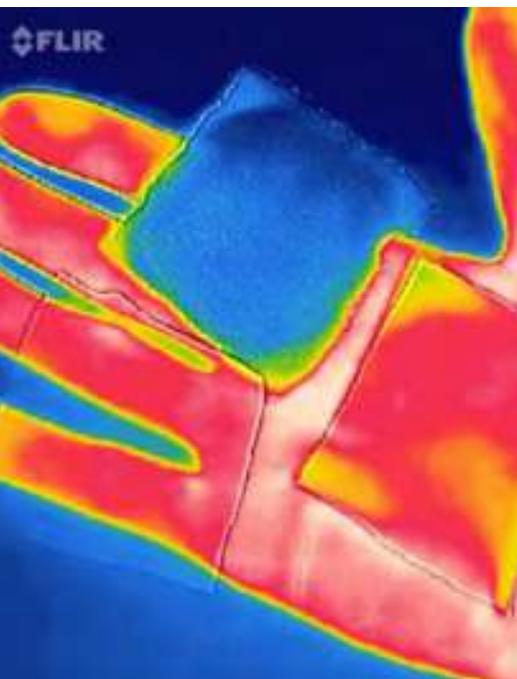
■ Connected Fabrics and Apparel

Smart clothing uses smart threads and small sensors to capture various physiological data. Nextiles is making

athletic apparel that monitors motion, pressure, bending, torque, and twisting for detailed feedback to athletes—including warning signs of fatigue. Rice University’s George R. Brown School of Engineering is using soft, flexible nanotube fibers sewn into athletic shirts to provide continuous electrocardiographic monitoring. Importantly, the shirt remains washable and stretchable. MIT’s Computer Science and Artificial Intelligence Laboratory developed socks, gloves, and a vest with “tactile electronics” that can coach athletes on improving their technique and detecting imbalances that could lead to injury, and provide real-time feedback during physical rehabilitation. Nanowear developed SimpleSense, a sash worn over the chest that’s lined with billions of nano-sensors. It can capture 85 patient vitals, including blood pressure and heart rate, respiration, lung volume and fluid, and temperature. Nanowear has partnered with health systems in New York City

to conduct a clinical trial in COVID-19 patients of its SimpleSense remote diagnostic monitoring platform. Redwood City, California startup Athos offers apparel that uses electromyography—which measures the electrical activity of muscle tissue—to provide athletes insights about training load, muscle activity, and quality of movement. Remote patient monitoring startup Siren makes connected socks to detect foot ulcers in diabetic patients by monitoring foot temperature, which can indicate inflammation, and sharing the data with their physician. A sleeve developed by Cipher Skin can track physical rehabilitation progress by analyzing arm movement and mobility, oxygen saturation, and heart rate.

Emerging Wearables



A nanoporous textile out of Duke University transmits thermal radiation to cool the human body.

Credit: Hsu Research Group - Duke University

■ Cloud-Based Wireless Body Area Networks

Wireless body area networks provide continuous monitoring of patients, diagnostics, and early warning signs of problems. The technology is deployed in remote patient monitoring, both in clinical settings and homes. Still in its infancy, this trend should accelerate as 5G networks reduce network lag and improve data security.

■ Smart Biohazard Wearables

Harvard University and MIT developed a face mask that can detect the SARS-CoV-2 virus. The scientists used synthetic biology to create synthetic circuits that send alerts when they're exposed to pathogens—and potentially identify chemical or biological threats, too. The technology could be integrated into personal protective equipment, such as clinical coats or gowns.

■ Commercial Full-Body Exoskeletons

Manufacturing and military settings are using wearable robots called exoskeletons to reduce fatigue and risk of injury. General Motors and Fiat are testing SuitX's industrial exoskeletons to support workers during heavy lifts. Salt Lake City-based Sarcos Technology and Robotics' full-body exoskeleton Guardian XO enables wearers to lift 200 pounds without any strain—ideal for freight handling workers. In 2022, Sarcos will sell its exoskeletons as part of a robotics-as-a-service plan, and T-Mobile will add 5G capabilities to its Guardian XT robots, which are based on the upper-body section of the Guardian XO. In Richmond, California, Ekso Bionics sells subscription-based access to its EksoHealth exosuits for stroke rehabilitation patients and its EksoWorks industrial vests that support workers in overhead lifts.

■ Wearable Air Conditioners

In April 2021, Sony introduced a more powerful wearable air conditioner called the Reon Pocket 2, available for sale only in Japan. The device, which has both cooling and warming features, automatically adjusts the temperature level based on your surroundings and activity level. Its software connects to your smartphone and can be used with any clothing item, using an accessory that wraps around your neck. Some brands like Descente sell shirts and clothing designed specifically to hold the device.

In China, Huazhong University of Science and Technology developed a metafabric to keep you 5 degrees Celsius cooler than traditional materials like cotton. The material reflects UV and visible light, while emitting infrared light and optimizing heat dissipation. Duke University researchers developed a nanoporous polyethylene textile that's

opaque to visible light but facilitates radiative cooling that keeps you 2 degrees Celsius cooler. These fabrics may provide an accessible alternative for people facing rising temperatures amid climate change.

■ Skinput Systems

Skinput uses human skin as an interface and effectively turns an arm and hand into an input device. When users tap a finger or a location on their arm, sensors translate the vibrations into specific actions, such as skipping a music track or answering a call. Google has integrated Soli—its low-energy radar sensor that detects motion on a microscopic scale—into the Nest Hub and Pixel 4. The sensor can detect gestures from a finger tap to full-body movement, enabling contactless control of any devices connected to the hub including smart speakers and thermostats.

Mature Wearables



Abbott Laboratories President and CEO Robert Ford announces a suite of new biowearables at CES 2022.

■ Watches

Smartwatches are monitoring more than heart rates, by providing blood pressure and temperature observations, and they're starting to draw conclusions about health status. The Apple Watch added oxygen saturation and menstrual cycle tracking that uses heart rate data to improve accuracy of predictions. Facebook is expected to launch its own smartwatch with fitness features and heart rate monitoring, and it won't need to be paired with a smartphone. Researchers at Duke University and the Stanford University School of Medicine found that smartwatch data on heart rate, temperature, and activity could indicate dehydration and abnormal blood counts. This research suggests that smartwatches could one day be used for early health intervention—long before a doctor requests a blood test.

■ Rings and Bracelets

Scientists from MIT's Computer Science and Artificial Intelligence Laboratory and Massachusetts General Hospital's Center for Artificial Intelligence created an open-source toolkit that lets users design and fabricate health-sensing devices like bracelets that detect distracted driving or bands that provide important data during physical therapy like muscle motion, strain, and tension. A patent application by Fitbit published in June 2021 describes a ring that monitors biometrics like blood oxygen levels. This would be the first new form factor introduced by the company that has focused on bands, and it could be a direct competitor to the Oura Ring.

■ Hearables and Earables

As many as 397 million hearables will be shipped by 2024, according to International Data Corp. forecasts. No longer just for listening to music or taking

a call, these in-ear wearables could monitor brain, cardiac, and respiratory function, too. University of California, Berkeley is testing ear EEG technology as a portable brain-computer interface for medical sleep monitoring and bio-feedback. Scientists have found various applications of in-ear EEG, including measuring employee attention in office settings and recognizing focal temporal lobe seizures. As the technology matures, an EEG alert could provide an early warning of a seizure and automatically call for help.

At the University of Illinois at Urbana-Champaign, researchers are looking at how earables could use acoustic augmented reality, which would let people navigate by following the sound of a voice. Sound mapping shifts the sound so that it appears to come from the direction in which the person should walk or turn. Imagine being guided through a morning run on any course you choose without ever getting lost.

Mature Wearables



InnoMake sensors warn users about obstacles with acoustic and visual warning signals and vibration feedback.

Credit: Tec-Innovation

■ Smart Glasses

Hype around smart glasses continued through 2021, from the launch of Xiaomi Smart Glasses to Facebook's Ray-Ban Stories to anticipation of smart glasses from Apple. Jio, a startup backed by Google and Facebook, announced it had developed smart glasses last year but has yet to launch them. Smart glasses and AR technology company Vuzix will collaborate with ambient computing company AmbiFi to make glasses for health care workers. Providers will use the glasses to view clinical workflows, get hands-free access to peer-reviewed and approved procedures, and transcribe notes via speech recognition technology.

■ Head-Mounted Displays

Virtual reality is commonly experienced through wearable headsets, but the next generation of the technology will collect personal information and bio-

metric data, including movement, pupil dilation, and heart rate to personalize simulated environments in real time. (See: *New Realities*.)

■ Smart Shoes

Austria's Tec-Innovation and Graz University of Technology created smart shoes with embedded sensors that alert people who are blind or visually impaired about obstacles in their path, using vibration feedback or an audible warning sent to a smartphone. Alerts are directional, so if a right shoe senses an obstacle, it sends a warning to the user's right earbud or vibrations to the right shoe.

■ Smart Gloves

Personal protective equipment manufacturer Mechanix Wear and thermal wearables technology company Clim8 created a smart glove that self-regulates temperature to keep hands comfortable.

IED Electronics developed smart gloves that measure quality and accuracy during manufacture and assembly. The system uses machine learning and data captured by an embedded gyroscope, accelerometers, and a microphone to indicate whether a user correctly assembled components. Bioservo Technologies' Ironhand 2.0 provides extra grip strength and endurance to the wearer. The glove reduces repetitive strain injuries and tracks ergonomic risk through analysis of use data.

An Offer You Can't Refuse • Mid-future pessimistic scenario



Subscriber: Julie White
Plan ID: 701-9923802-8100257

Date of Service: August 26, 2030

Dear Julie White:

On behalf of Amazon Care, I want to thank you for allowing us to serve you during your recent visit. Below is an invoice for the medical services rendered, with a breakdown of your pricing options.

The quality of our services depends on our members opting in to share data, but we understand that choice may not fit every situation. The first column indicates the payment requested if you choose to withhold your health data. If, however, you decide to support our efforts to continually learn and improve our services, we offer a special discount, which is reflected in our second pricing option. Please indicate your selection in the member portal within 10 days, and the appropriate payment will be deducted from your Amazon Coin balance.

Thank you for being a valued member. We hope we have met your expectations and that you are on a speedy road to recovery.

Description	Price 1 (Data Opt-Out)	Price 2 (Data Opt-In)
Flexible Bioelectronic Bandage	\$23,000	\$20
Smart Thread Sutures	\$467,000	\$460
BioMesh Drug Delivery Tattoo	\$512,000	\$540
Ama-skin Electronic Skin Monitoring—10 days	\$893,000	Included with Prime Care
TOTAL	\$1,895,000	\$1,020



How these trends impact your company



STRATEGY

Healthcare executives must develop long-term strategic scenarios in 2022. As we enter year three of the global COVID-19 pandemic, lingering uncertainties about lasting impacts, along with the staggering pace of innovation, mean ongoing disruption is likely. It would be a mistake to focus only on 3 or 5-year strategic plans while big tech players (Amazon, Facebook, Google, Apple) and well-capitalized start-ups are playing a longer game. Executives and their teams must confront their cherished beliefs about what healthcare has always been—and develop new mental models for what it could be in the future.



INNOVATION

Wearable devices are moving from the fringe to the mainstream, and consumers are looking for actionable insights. They are also more health-conscious in the wake of the pandemic. Additional factors include the rollout of 5G networks and relaxed rules on telemedicine and remote patient monitoring. This year, Chief Innovation Officers and their teams should identify moonshots and develop strategic scenarios to develop longer-range innovation roadmaps.



R & D

R&D teams should pursue moonshot ideas—new therapeutics, embeddable devices, patient systems, even clinics that operate without a brick-and-mortar location—and prioritize high-impact bets. As excitement grows for health tech, corporate R&D teams will be pushed to productize their work. Unfortunately, there has historically been too much emphasis on “D,” without enough on “R.” This year, teams will be confronted with antsy boards of directors and enthusiastic chief marketing officers who want to see next-generation health tech in the marketplace. Longer-range roadmaps in health, medical and wearable space can balance near-term expectations with more aggressive research agendas.



GROWTH

Paradoxically, the global pandemic is unlocking new growth across the health, medical and wearable ecosystems. As emerging technologies bring the power of the laboratory into our homes and AI expands the possibilities for remote diagnosis, there will be knock-on effects realized this decade. Rehearsing the futures of healthcare using strategic foresight has never been more important.

Key Questions

We recommend using this report to support your strategic foresight activity in the coming year. Every executive team should begin by asking these questions:

1

- ▶ How could home-based diagnostic systems disrupt our business?

- ▶ If direct-to-consumer tests threaten our profitability, can we develop new products or services to compete with upstarts?

2

- ▶ How might DIY consumer health products unlock new growth opportunities for our business?

- ▶ If we sourced more biometric data, could we develop new insights about our customers?

3

- ▶ What parts of our business make us a target for disruption?

- ▶ How could new business models introduced by emerging players in health tech, wearables, and fitness pose a threat?

Selected Sources

"7 Recent Big Tech Partnerships in Healthcare: Amazon, Google & More." Accessed September 7, 2021. <https://www.beckershospitalreview.com/digital-transformation/7-recent-big-tech-partnerships-in-health-care-amazon-google-more-2.html>.

STAT. "A New Study Points to the Power of Wearables to Predict Infections," September 29, 2021. <https://www.statnews.com/2021/09/29/wearables-predict-presymptomatic-infections-study/>.

FierceHealthcare. "Accolade Plans to Acquire Virtual Primary Care Provider PlushCare in a \$450M Stock and Cash Deal." Accessed August 14, 2021. <https://www.fiercehealthcare.com/tech/accolade-plans-to-acquire-virtual-primary-care-provider-plushcare-a-450m-deal>.

"Acousto-Magnetic Micro/Nanorobots for Biomedical Applications | SONOBOTS Project | Fact Sheet | H2020 | CORDIS | European Commission." Accessed October 7, 2021. <https://cordis.europa.eu/project/id/853309>.

Allam, Chantal. "Raleigh's VitalFlo Lands \$2.1M to Scale Predictive Medicine Platform." Hypepotamus, July 16, 2021. <https://hypepotamus.com/news/vitaflo-north-carolina/>.

"Amazon Care Approached Big Health Insurers to Expand Coverage." Accessed September 7, 2021. <https://www.beckershospitalreview.com/strategy/amazon-care-approached-big-health-insurers-to-expand-coverage.html>.

"Amazon Halo Could Upend Connected Fitness," September 30, 2021. <https://www.pymnts.com/news/retail/2021/amazon-halo-expansion-could-upend-connected-fitness-space/>.

ScienceDaily. "An Intelligent Soft Material That Curls Under Pressure or Expands When Stretched." Accessed October 6, 2021. <https://www.sciencedaily.com/releases/2021/02/210224113042.htm>.

American Chemical Society. "An Intelligent Soft Material That Curls under Pressure or Expands When

Stretched (Video)." Accessed October 6, 2021. <https://www.acs.org/content/acs/en/pressroom/presspacs/2021/acs-presspac-february-24-2021/an-intelligent-soft-material-that-curls-under-pressure-or-expands-when-stretched-video.html>.

"AppliedVR Completes Pivotal Trial Finding Virtual Reality Is a Holistic Treatment for Chronic Pain," February 24, 2021. <https://www.businesswire.com/news/home/20210224005301/en/AppliedVR-Completes-Pivotal-Trial-Finding-Virtual-Reality-Is-a-Holistic-Treatment-for-Chronic-Pain>.

STAT. "As Tech Giants Double down on Sleep Tracking, Providers Want More Proof," August 11, 2021. <https://www.statnews.com/2021/08/11/amazon-google-double-down-sleep-tracking-with-radar-wearables/>.

STAT. "At a Rural ICU, Covid-19's Summer Surge Put Telehealth to the Test," October 5, 2021. <https://www.statnews.com/2021/10/05/telemedicine-icu-covid19-hospitals/>.

Bayoumy, Karim, Mohammed Gaber, Abdallah Elshafeey, Omar Mhaimeed, Elizabeth H. Dineen, Francoise A. Marvel, Seth S. Martin, et al. "Smart Wearable Devices in Cardiovascular Care: Where We Are and How to Move Forward." *Nature Reviews Cardiology* 18, no. 8 (August 2021): 581-99. <https://doi.org/10.1038/s41569-021-00522-7>.

Bonnechère, Bruno, Malgorzata Klass, Christelle Langley, and Barbara Jacquelyn Sahakian. "Brain Training Using Cognitive Apps Can Improve Cognitive Performance and Processing Speed in Older Adults." *Scientific Reports* 11, no. 1 (June 10, 2021): 12313. <https://doi.org/10.1038/s41598-021-91867-z>.

"Brain Computer Interface Market Is Expected to Grow at a CAGR of around 13.8% from 2020-2027." Accessed September 29, 2021. https://www.acumenresearchandconsulting.com/brain-computer-interface-market?utm_source=morning_brew.

IEEE Spectrum. "Brain Signals Can Drive Exoskeleton Parts Better With Therapy," April 23, 2021. <https://spec>

<trum.ieee.org/brain-computer-interface-exoskeleton-neural-link>.

"Brain Training Habits Are Not Associated with Generalized Benefits to Cognition: An Online Study of over 1000 'Brain Trainers' - PsycNET." Accessed October 2, 2021. <https://doi.apa.org/doiLand-ing?doi=10.1037%2F%2F0000773>.

Caeiro-Rodríguez, Manuel, Iván Otero-González, Fernando A. Mikic-Fonte, and Martín Llamas-Nistal. "A Systematic Review of Commercial Smart Gloves: Current Status and Applications." *Sensors (Basel, Switzerland)* 21, no. 8 (April 10, 2021): 2667. <https://doi.org/10.3390/s21082667>.

STAT. "Carbon Health Pushes Further into Home Care with Remote Monitoring Buy," October 5, 2021. <https://www.statnews.com/2021/10/05/carbon-health-alertive-healthcare/>.

"Concurrent Aerobic Exercise and Cognitive Training to Prevent Alzheimer's in At-Risk Older Adults (The Exergame Study) | National Institute on Aging." Accessed October 2, 2021. <http://www>

Selected Sources

nia.nih.gov/clinical-trials/virtual-reality-exercise-and-cognitive-training-program-prevent.

Culliford, Elizabeth. "Facebook Unveils Its First Smart Glasses." Reuters, September 9, 2021, sec. Technology. <https://www.reuters.com/technology/facebook-unveils-its-first-smart-glasses-2021-09-09/>.

Duke Pratt School of Engineering. "Data from Smartwatches Can Help Predict Clinical Blood Test Results," May 24, 2021. <https://pratt.duke.edu/about/news/data-smartwatches-can-help-predict-clinical-blood-test-results>.

"Ear EEG Home." Accessed October 9, 2021. https://www.commsp.ee.ic.ac.uk/~csp-mandic/html/projects/ear_eeg/.

ZME Science. "Electronic Textiles Could Turn Clothes into Wearable Electronics," March 10, 2021. <https://www.zmescience.com/future/electronic-textiles-could-turn-clothes-into-wearable-electronics/>.

Waterloo News. "Engineers Combine AI and Wearable Cameras in Self-Walking Robotic Exoskeletons," March 15, 2021. <https://uwaterloo.ca/news/media/engineers-combine-ai-and-wearable-cameras-self-walking>.

MIT News | Massachusetts Institute of Technology. "Engineers Create a Programmable Fiber." Accessed October 7, 2021. <https://news.mit.edu/2021/programmable-fiber-0603>.

MIT Technology Review. "Facebook Is Ditching Plans to Make an Interface That Reads the Brain." Accessed September 16, 2021. <https://www.technologyreview.com/2021/07/14/1028447/facebook-brain-reading-interface-stops-funding/>.

"First-Ever Transient Pacemaker Harmlessly Dissolves in Body." Accessed October 7, 2021. <https://news.northwestern.edu/stories/2021/06/first-ever-transient-pacemaker-harmlessly-dissolves-in-body/>.

"Foldable, Organic and Easily Broken down: Why DNA Is the Material of

Choice for Nanorobots | Research and Innovation." Accessed October 7, 2021. <https://ec.europa.eu/research-and-innovation/en/horizon-magazine/foldable-organic-and-easily-broken-down-why-dna-material-choice-nanorobots>.

Garcia, Laura M., Brandon J. Birchhead, Parthasarathy Krishnamurthy, Josh Sackman, Ian G. Mackey, Robert G. Louis, Vafi Salmasi, Todd Maddox, and Beth D. Darnall. "An 8-Week Self-Administered At-Home Behavioral Skills-Based Virtual Reality Program for Chronic Low Back Pain: Double-Blind, Randomized, Placebo-Controlled Trial Conducted During COVID-19." *Journal of Medical Internet Research* 23, no. 2 (February 22, 2021): e26292. <https://doi.org/10.2196/26292>.

Gavelin, Hanna Malmberg, Christopher Dong, Ruth Minkov, Alex Bahar-Fuchs, Kathryn A. Ellis, Nicola T. Lautenschlager, Maddison L. Mellow, et al. "Combined Physical and Cognitive Training for Older Adults with and without Cognitive Impairment: A Systematic Review and Network Meta-Analysis of Randomized Controlled Trials."

Ageing Research Reviews 66 (March 2021): 101232. <https://doi.org/10.1016/j.arr.2020.101232>.

Guo, Hongchen, Yu Jun Tan, Ge Chen, Zifeng Wang, Glenys Jocelin Susanto, Hian Hian See, Zijie Yang, Zi Wei Lim, Le Yang, and Benjamin C. K. Tee. "Artificially Innervated Self-Healing Foams as Synthetic Piezo-Impedance Sensor Skins." *Nature Communications* 11, no. 1 (November 12, 2020): 5747. <https://doi.org/10.1038/s41467-020-19531-0>.

Hemmsen, Martin, Kaare Mikkelsen, Mike Rank, and Preben Kidmose. "272 Long-Term Monitoring of Trait-like Characteristics of the Sleep Electroencephalogram Using Ear-EEG." *Sleep* 44, no. Supplement_2 (May 1, 2021): A109. <https://doi.org/10.1093/sleep/zsab072.271>.

Hölle, Daniel, Joost Meekes, and Martin G. Bleichner. "Mobile Ear-EEG to Study Auditory Attention in Everyday Life." *Behavior Research Methods*, March 15, 2021. <https://doi.org/10.3758/s13428-021-01538-0>.

Hong, Xiangfei, You Chen, Jijun Wang, Yuan Shen, Qingwei Li, Binglei Zhao, Xiaoli Guo, Wei Feng, Wenyuan Wu, and Chunbo Li. "Effects of Multi-Domain Cognitive Training on Working Memory Retrieval in Older Adults: Behavioral and ERP Evidence from a Chinese Community Study." *Scientific Reports* 11, no. 1 (January 13, 2021): 1207. <https://doi.org/10.1038/s41598-020-79784-z>.

Jabeen, Tallat, Humaira Ashraf, and Ata Ullah. "A Survey on Healthcare Data Security in Wireless Body Area Networks." *Journal of Ambient Intelligence and Humanized Computing* 12, no. 10 (October 1, 2021): 9841–54. <https://doi.org/10.1007/s12652-020-02728-y>.

Jackson, James C. "Cognitive Training in Survivors of Covid-19: A Randomized Trial." Clinical trial registration. *clinicaltrials.gov*, July 13, 2021. <https://clinicaltrials.gov/ct2/show/NCT04956887>.

Jamieson, Kathleen Hall. "How to Debunk Misinformation about COVID, Vaccines and Masks." *Scientific American*. Accessed September 14, 2021. <https://www.scientificamerican.com/article/how-to-debunk-misinformation-about-covid-vaccines-and-masks/>

Selected Sources

Jiang, Yiwen, Aydin Sadeqi, Eric L. Miller, and Sameer Sonkusale. "Head Motion Classification Using Thread-Based Sensor and Machine Learning Algorithm." *Scientific Reports* 11, no. 1 (January 29, 2021): 2646. <https://doi.org/10.1038/s41598-021-81284-7>.

Jung, Yei Hwan, Jae-Hwan Kim, and John A. Rogers. "Skin-Integrated Vibrotactile Interfaces for Virtual and Augmented Reality (Adv. Funct. Mater. 39/2021)." *Advanced Functional Materials* 31, no. 39 (2021): 2170291. <https://doi.org/10.1002/adfm.202170291>.

Kang, Jae Myeong, Nambeom Kim, Sook Young Lee, Soo Kyun Woo, Geumjin Park, Byeong Kil Yeon, Jung Woon Park, et al. "Effect of Cognitive Training in Fully Immersive Virtual Reality on Visuospatial Function and Frontal-Occipital Functional Connectivity in Pre-dementia: Randomized Controlled Trial." *Journal of Medical Internet Research* 23, no. 5 (May 6, 2021): e24526. <https://doi.org/10.2196/24526>.

Kim, Hojoong, Young-Tae Kwon, Hyo-Ryong Lim, Jong-Hoon Kim, Yun-Soung Kim, and Woon-Hong Yeo. "Recent Advances in Wearable Sensors and Integrated Functional Devices for Virtual and Augmented Reality Applications (Adv. Funct. Mater. 39/2021)." *Advanced Functional Materials* 31, no. 39 (2021): 2170289. <https://doi.org/10.1002/adfm.202170289>.

Lee, KunHyuck, Xiaoyue Ni, Jong Yoon Lee, Hany Arafa, David J. Pe, Shuai Xu, Raudel Avila, et al. "Mechano-Acoustic Sensing of Physiological Processes and Body Motions via a Soft Wireless Device Placed at the Suprasternal Notch." *Nature Biomedical Engineering* 4, no. 2 (February 2020): 148–58. <https://doi.org/10.1038/s41551-019-0480-6>.

Lee, Yeongjun, Jong Won Chung, Gae Hwang Lee, Hyunbum Kang, Joo-Young Kim, Chisung Bae, Hyunjun Yoo, et al. "Standalone Real-Time Health Monitoring Patch Based on a Stretchable Organic Optoelectronic System." *Science Advances* 7, no. 23 (n.d.): eabg9180. <https://doi.org/10.1126/sciadv.abg9180>.

Mahmood, Musa, Shinjae Kwon, Hojoong Kim, Yun Soung Kim, Panote Siriraraya, Jeongmoon Choi, Boris Otkhmezuri, et al. "Wireless Soft Scalp Electronics and Virtual Reality System for Motor Imagery Based Brain-Machine Interfaces." *Advanced Science*, July 17, 2021, 2101129. <https://doi.org/10.1002/advs.202101129>.

Makin, Simon. "Pathogen-Sensing Mask Could Detect COVID Infection." *Scientific American*. Accessed October 8, 2021. <https://www.scientificamerican.com/article/pathogen-sensing-mask-could-detect-covid-infection/>

MIT News | Massachusetts Institute of Technology. "Making Health and Motion Sensing Devices More Personal." Accessed October 9, 2021. <https://news.mit.edu/2021/making-health-motion-sensing-devices-more-personal-eit-kit-0922>.

Morris, Betsy. "Diets Engineered to Work With Your Microbiome Are Latest Startup Craze." *Wall Street Journal*, June 28, 2021, sec. Life. <https://www.wsj.com/articles/diets-engineered-to-work-with-your-microbiome-are-latest-startup-craze-11624899685>.

Moses, David A., Sean L. Metzger, Jessie R. Liu, Gopala K. Anumanchipalli, Joseph G. Makin, Pengfei F. Sun, Josh Chartier, et al. "Neuroprosthesis for Decoding Speech in a Paralyzed Person with Anarthria." *New England Journal of Medicine* 385, no. 3 (July 15, 2021): 217–27. <https://doi.org/10.1056/NEJMoa2027540>.

Mount Sinai Health System. "Mount Sinai Study Finds Wearable Devices Can Detect COVID-19 Symptoms and Predict Diagnosis | Mount Sinai - New York." Accessed October 9, 2021. <https://www.mountsinai.org/about/newsroom/2021/mount-sinai-study-finds-wearable-devices-can-detect-covid19-symptoms-and-predict-diagnosis-pr>.

"MPs Urge Government to Review Regulations for Direct-to-Consumer Genetic Testing - Committees - UK Parliament." Accessed October 2, 2021. <https://committees.parliament.uk/committee/135/science-and-technology-committee/news/156039/mps-urge-government-to-review-regulations-for-directtoconsumer-genetic-testing/>.

University of Birmingham. "Nanomaterials Shape and Form Influences Their Ability to Cross the Blood Brain Barrier - Study." Accessed October 7, 2021. <https://www.birmingham.ac.uk/news/latest/2021/07/nanomaterials-blood-brain-barrier-study.aspx>.

"Nanorobots Move Acoustically to Deliver Cancer Drugs. - ASME." Accessed October 7, 2021. <https://www.asme.org/topics-resources/content/acoustically-triggered-nanorobotics-hold-promise-for-cancer-treatment>.

"New 'mirror' Fabric Can Cool Wearers by Nearly 5°C." Accessed October 9, 2021. <https://www.science.org/content/article/new-mirror-fabric-can-cool-wearers-nearly-5-c>.

Fitbit Blog. "New Study from Fitbit Seeks to Advance COVID-19 and Flu Research with Early Detection," May 21, 2020. <https://blog.fitbit.com/covid-19-study/>.

Selected Sources

"Next-generation wearable electronics - Professor Donghee Son Laboratory." Accessed October 9, 2021. <https://bio-electronics.skku.edu/news/next-generation-wearable-electronics/>.

Nguyen, Peter Q., Luis R. Soenksen, Nina M. Donghia, Nicolaas M. Angeant-Mari, Helena de Puig, Ally Huang, Rose Lee, et al. "Wearable Materials with Embedded Synthetic Biology Sensors for Biomolecule Detection." *Nature Biotechnology*, June 28, 2021, 1–9. <https://doi.org/10.1038/s41587-021-00950-3>.

Norman, Sumner L., David Maresca, Vassilios N. Christopoulos, Whitney S. Griggs, Charlie Demene, Mickael Tanter, Mikhail G. Shapiro, and Richard A. Andersen. "Single-Trial Decoding of Movement Intentions Using Functional Ultrasound Neuroimaging." *Neuron* 109, no. 9 (May 5, 2021): 1554–1566. e4. <https://doi.org/10.1016/j.neuron.2021.03.003>.

NUS researchers create AiFoam for robots to interact intelligently with their surroundings. "NUS Researchers

Create AiFoam for Robots to Interact Intelligently with Their Surroundings." Accessed October 6, 2021. <https://news.nus.edu.sg/nus-researchers-create-aifoam-for-robots-to-interact-intelligently-with-their-surroundings/>.

"Playing a Virtual Reality Game during Medical Procedures Can Reduce Pain and Anxiety in Children | Keck School of Medicine of USC." Accessed September 15, 2021. <https://keck.usc.edu/playing-a-virtual-reality-game-during-medical-procedures-can-reduce-pain-and-anxiety-in-children/>.

Proulx, Ben. "U of A Project Aims to Use AI to Help Patients with Respiratory Issues." Accessed September 30, 2021. <https://www.ualberta.ca/folio/2021/08/u-of-a-project-aims-to-use-ai-to-help-patients-with-respiratory-issues.html>.

National Institutes of Health (NIH). "RADx." Accessed August 10, 2021. <https://www.nih.gov/research-training/medical-research-initiatives/radx>.

Facebook Technology. "Ray-Ban and Facebook Introduce Ray-Ban Stories, First-Generation Smart Glasses," September 9, 2021. <https://tech.fb.com/ray-ban-and-facebook-introduce-ray-ban-stories-first-generation-smart-glasses/>.

Brown University. "Researchers Take Step toward Next-Generation Brain-Computer Interface System." Accessed September 16, 2021. <https://www.brown.edu/news/2021-08-12/neurograins>.

Shi, Xiang, Yong Zuo, Peng Zhai, Jiahao Shen, Yangyiwei Yang, Zhen Gao, Meng Liao, et al. "Large-Area Display Textiles Integrated with Functional Systems." *Nature* 591, no. 7849 (March 2021): 240–45. <https://doi.org/10.1038/s41586-021-03295-8>.

Silva Souto, Carlos F. da, Wiebke Pätzold, Karen Insa Wolf, Marina Paul, Ida Matthiesen, Martin G. Bleichner, and Stefan Debener. "Flex-Printed Ear-EEG Sensors for Adequate Sleep Staging at Home." *Frontiers in Digital Health* 3 (2021): 66. <https://doi.org/10.3389/fdgth.2021.688122>.

Simonite, Tom. "Google Launches a New Medical App—Outside the US." *Wired*. Accessed September 7, 2021. <https://www.wired.com/story/google-launches-medical-app-outside-us/>.

"Smart Clothes' That Can Measure Your Movements | MIT CSAIL," March 24, 2021. <https://www.csail.mit.edu/news/smart-clothes-can-measure-your-movements>.

Medscape. "Smart Toilet' With AI Scans Stool for Blood, Consistency." Accessed August 10, 2021. <http://www.medscape.com/viewarticle/951684>.

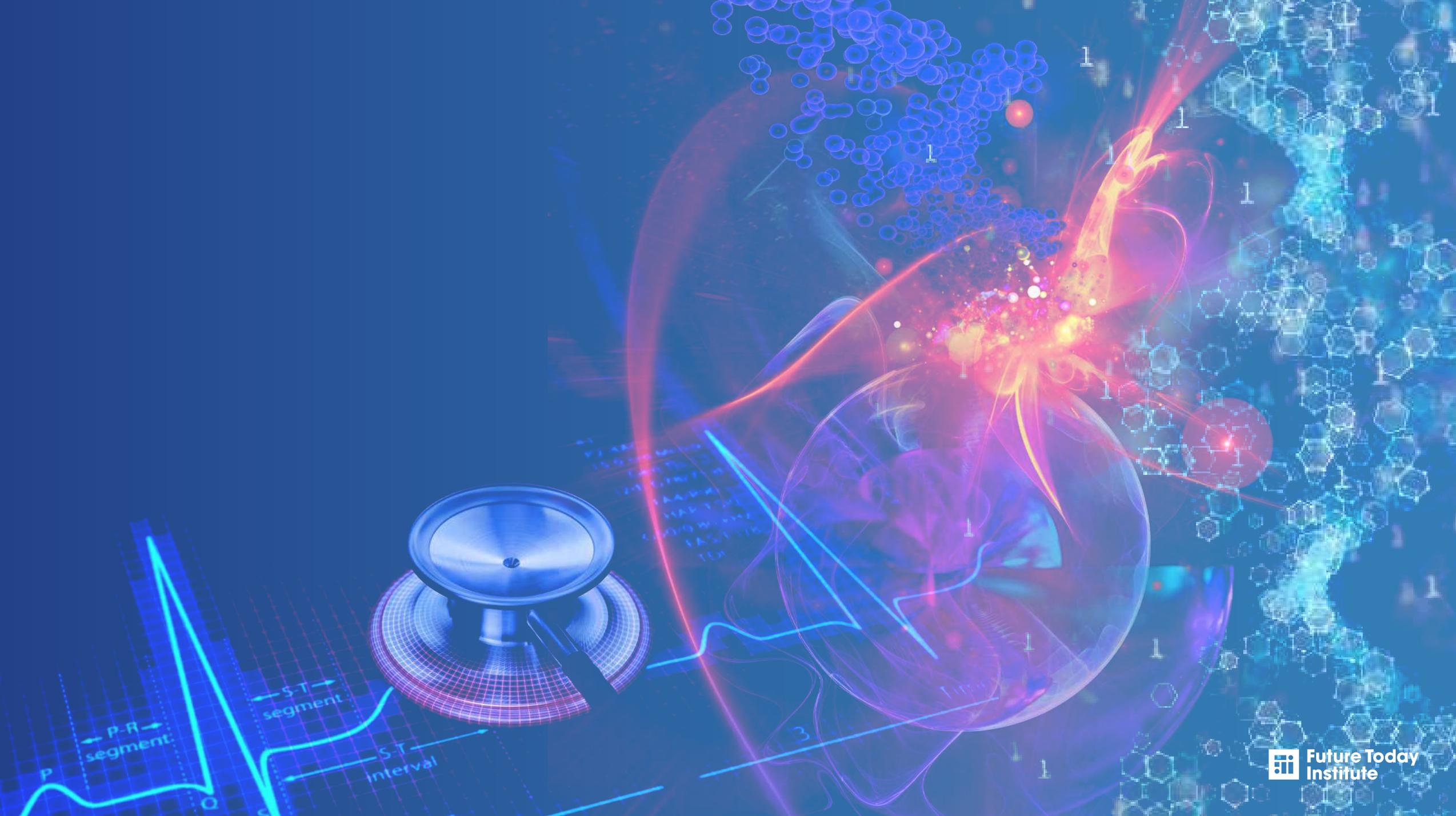
Sprague, Briana N. "Cognitive Training, Mobility, and Everyday Life." *The Lancet Healthy Longevity* 2, no. 9 (September 1, 2021): e533–34. [https://doi.org/10.1016/S2666-7568\(21\)00200-2](https://doi.org/10.1016/S2666-7568(21)00200-2).

Takaloo, Saeed, and Mahdi Moghimi Zand. "Wearable Electrochemical Flexible Biosensors: With the Focus on Affinity Biosensors." *Sensing and Bio-Sensing Research* 32 (June 1, 2021): 100403. <https://doi.org/10.1016/j.sbsr.2021.100403>.

Tavera, Carlos A., Jesús H. Ortiz, Osamah I. Khalaf, Diego F. Saavedra, and Theyazn H. H. Aldhyani. "Wearable Wireless Body Area Networks for Medical Applications." *Computational and Mathematical Methods in Medicine* 2021 (April 24, 2021): 5574376. <https://doi.org/10.1155/2021/5574376>.

Taylor, Lauren W., Steven M. Williams, J. Stephen Yan, Oliver S. Dewey, Flavia Vitale, and Matteo Pasquali. "Washable, Sewable, All-Carbon Electrodes and Signal Wires for Electronic Clothing." *Nano Letters* 21, no. 17 (September 8, 2021): 7093–99. <https://doi.org/10.1021/acs.nanolett.1c01039>.

Ugarte, Rodrigo. "Misinformation Is Everybody's Problem Now." *Items (blog)*. Accessed September 14, 2021. <https://items.ssrc.org/covid-19-and-the-social-sciences/mediated-crisis/misinformation-is-everybodys-problem-now/>.



Home of Things

Tech trends influencing consumer electronics, home automation, and digital living.

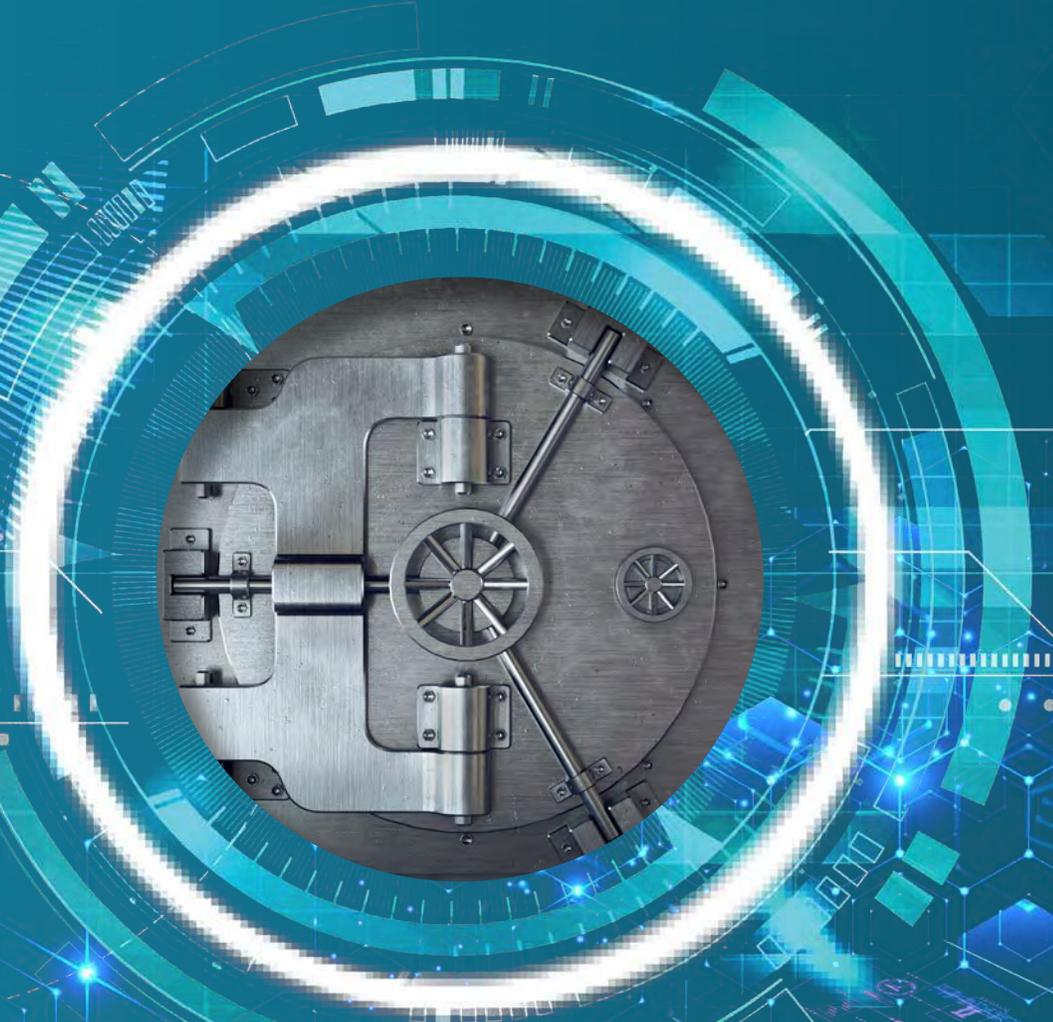


Table of Contents

- 309** Key Insights
- 310** Multi-User Platforms
- 311** HoT Platforms
- 312** Scenario: The Royal Flush
- 313** Service Bots
- 314** Cleaning Bots
- 316** Smart Home Gyms
- 317** Smart Kitchens
- 318** Scenario: What To Eat
- 319** Adaptable Surfaces
- 320** Sleep Tech
- 321** Smart Home Digital Emissions
- 322** Retrofitting Old Homes With New Technology
- 323** Right to Repair
- 324** Securing the HoT
- 326** Application
- 327** Key Questions
- 328** Selected Sources

Key Insights

- * Demand for Home of Things (HoT) connectivity is being driven by working, exercising, and learning from home.
- * HoT platforms increasingly service entire households, rather than just one person. As a result, consumers may be more likely to adopt electronics that work seamlessly within their smart home.
- * Tech companies, backed by eager investors, want to control our sleep using sensors, microphones, and artificial intelligence.
- * Robots are starting to perform repetitive tasks around the home that humans can't—or won't—do on their own.
- * Adaptable surfaces—in kitchens, home offices, and living rooms—are being developed to bridge the gap between physical and digital interactions.
- * Homes are becoming sentient: Automated systems sense and adjust temperature, sound, light, and other functions in real time to support families.
- * Smart homes contribute to climate change in the form of digital emissions.
- * Lawmakers are enacting “right to repair” legislation, forcing appliance manufacturers to allow repairs and use interchangeable parts and common standards.
- * The HoT is notorious for security vulnerabilities. In 2022, hackers will increasingly target HoT devices with botnets and malware attacks.
- * While HoT devices are growing in popularity, interoperability still lags.

1ST YEAR ON THE LIST

Multi-User Platforms



Several people can now access a single smart home using individual accounts.

KEY INSIGHT

Platforms are increasingly servicing entire households, rather than just one person. This allows for easy use and personalization—but it also consolidates the Home of Things (HoT) into just a few corporate ecosystems.

EXAMPLES

Digital assistants are a good example of a multi-user platform: Systems like Alexa and Google Home now recognize individual people's voices and can respond to their specific needs, such as checking a calendar or logging in to a third-party streaming service (like Spotify). Within the Apple ecosystem, guests to a home can link their iPhones to a HomePod speaker system and stream music—without needing to authenticate or ask for Wi-Fi passwords. By enabling multiple users on shared smart devices, platforms can expand the reach of their ecosystems and give customers ever-increasing incentives to place their entire lives within a single ecosystem.

DISRUPTIVE IMPACT

In the past, smart devices and personal computing typically had a single user or administrator. Smart home devices are pushing forward software solutions that enable multiple users to operate HoT gear with the same fluidity and functionality as if it were a personal device. This has profound implications for interoperability as well as business models. Consumers may be more likely to adopt technology and platforms that work seamlessly with other devices in their households.

EMERGING PLAYERS

- National Institute of Standards and Technology
- Connectivity Standards Alliance
- Electronic Frontier Foundation
- Qualcomm
- Samsung
- Apple
- Google
- Amazon

8TH YEAR ON THE LIST

HoT Platforms



KEY INSIGHT

Platforms provide the brains that power smart devices, but few devices work across platforms, resulting in homes that must be exclusively centered around either Google products, Apple products, or Amazon products.

Without interoperability, smart home platforms force the question of what kind of household you should run—an Apple, Google, or Amazon household?

Image credit: Tada Images/Shutterstock.com.

EXAMPLES

The home has become a key battleground for Big Tech companies churning out interconnected and smart home products and software. For Big Tech, the home is the entry point to new revenue streams, data, and captive audiences. For customers, the home is full of repetitive menial tasks ripe for automation. Think: alerts that tell you if you failed to turn off the stove or automations that open window shades when you hit your lightest sleep cycle. Google Home connects to thousands of devices, while Amazon Alexa boasts 100,000 skills, all of which can be layered on top of each other. Apple has boosted the number of connected devices within the Apple ecosystem, such as having the HomePod act as the speaker for the AppleTV.

DISRUPTIVE IMPACT

Home of Things devices are growing in popularity, but interoperability still lags. The Connectivity Standards Alliance, formerly the Zigbee Alliance, developed a new protocol called Matter, which acts as an interface between devices. Non-platform manufacturers will continue to leverage protocols like Matter to provide hardware and software that work on multiple platforms, but a Google speaker still won't share rich data with an Amazon Alexa-powered microwave. Because richer data delivers better customer experiences, consumers must choose a provider and stick with it throughout its devices, effectively becoming a Google, Apple, or Amazon household.

EMERGING PLAYERS

- National Institute of Standards and Technology
- Connectivity Standards Alliance
- Matter

The Royal Flush • Mid-future optimistic scenario

The Eco Grand is innovation at its best

DID YOU KNOW?

- **Water Savings.** Only 1 cup water per flush.
- **Converts Waste to Energy.** A family of 4 creates 2 kW of energy/day —the same energy a laptop requires per week.
- **Delivering Value.** The more you go, the more digital credits you earn to be redeem for earth-friendly products.

UP TO 200+ HEALTH DIAGNOSTIC TESTS

Urinary tract infections	Diabetes
Kidney disorders	Colon Cancer
Liver problems	...and more

! After an alert, test results are sent to your doctor, and appointments are automatically scheduled.

PLUS:

- Healthy nudges to drink more water, reduce sugar or alcohol, suggest healthier alternatives
- Coordinates shopping with smart fridge
- Monitors virus spread



7TH YEAR ON THE LIST

Service Bots



Consumer robots are increasingly tackling care-giving tasks.

KEY INSIGHT

Robots perform repetitive tasks around the home that humans can't—or won't do.

EXAMPLES

Consumer robots are increasingly tackling household chores like vacuuming, cleaning windows, mowing the lawn, and even cleaning the grill. The Worx Landroid is an automatic lawn mower that continuously learns about the landscape it maintains. While not yet on the market, FoldiMate is a robot built to fold clothing. Budgee, from Five Elements Robotics, is an assistive robot designed to follow people and carry items—laundry, stuffed animals—as they move around the house. Service bots are increasingly performing more advanced tasks, such as autonomously using elevators to move between floors of a building.

DISRUPTIVE IMPACT

As availability and functionality improve and costs drop, autonomous single-function robots will be ready to perform the repetitive tasks typically done by humans. Meanwhile, improved computer interfaces will make it easier for human operators to perform more complex tasks with robotic assistance.

EMERGING PLAYERS

- Arizona State University Robotics
- University of Pennsylvania GRASP Laboratory
- Carnegie Mellon University Robotics Institute
- Sony
- LG Electronics
- iRobot Roomba
- Georgia Tech
- Lego Education

2ND YEAR ON THE LIST

Cleaning Bots



LG's autonomous cleaning bots are working in hospitals and caregiving centers.

KEY INSIGHT

Robots capable of sterilizing and disinfecting, once used only in hospitals, are making their way into our offices and homes.

EXAMPLES

The CLOi autonomous robot from LG Electronics looks like a narrow space heater on wheels. It uses ultraviolet light to disinfect high-touch, high-traffic areas in retail, hospitality, and corporate settings. There are three types of UV radiation (UVA, UVB, and UVC), and LG uses UVC, which is approved by the U.S. Food and Drug Administration for disinfecting nonporous surfaces, water, and air. Signify, which makes LED lighting systems, developed a desk lamp that disinfects nearby surfaces when turned on. The Rockubot uses smart mapping to apply an ultraviolet light to disinfect such surfaces as hotel beds and cell-phones, while simultaneously playing Bluetooth music and providing wireless charging.

DISRUPTIVE IMPACT

While some hospitals and office buildings experimented with disinfecting robots before COVID-19, these bots hit the mainstream amid continued lockdowns and fears about the spreading virus. Demand for UV robots is growing in schools, health care facilities, offices, and industrial settings, especially as prices fall.

EMERGING PLAYERS

- LG Electronics
- Xenex
- Prescientx
- Ubtech Robotics
- MIT Computer Science and Artificial Intelligence Laboratory



Technology holds infinite possibilities for mankind and will one day rid society of all its ills. Soon, technology will effect the way you live your life everyday. No more tedious work. Leaving more time for leisure activities and enjoying the sweet life.

— Howard Stark, in *Iron Man 2*



8TH YEAR ON THE LIST

Smart Home Gyms



Consumers are bringing the gym into their homes with connected equipment.

KEY INSIGHT

The latest smart fitness devices bring the best of the gym right into your home.

EXAMPLES

Subscription-based workout apps have disrupted the gym membership. When gyms closed due to COVID-19, demand for connected fitness systems spiked. Many gym hardware manufacturers are creating products that are specifically designed for the home but bring in the community and coaching elements of the best in-person fitness centers. Mirror by Lululemon is a functional piece of furniture designed to provide expert instruction via videoconferencing, real time optimization, community, and customized playlists. Interactive fitness mirror Tonal comes with adjustable arms for resistance and weight training. The system automatically detects your performance and adjusts the resistance for your workout. Tempo, a free weight machine with a 42-inch HD touchscreen and 16 weighted plates, uses 3D mapping to adjust your form in real time.

DISRUPTIVE IMPACT

Once considered a last resort, exercising at home is now a desirable, affordable luxury. Brands offer monthly subscription packages equivalent to the price of a standard gym membership. These features are regularly charged on top of the cost of the hardware and are occasionally required for the hardware to even function (as was the case with Peloton Tread+, a smart treadmill that received a software update that accidentally made the treadmill inoperable without an active Peloton subscription). Many of these value-added services are relying on data analysis and artificial intelligence to provide personalized recommendations and feedback, all while generating significant new datasets and troves of information on personal fitness combined with fitness tracking over time. While most of these datasets are not currently interoperable, players like Apple are beginning to connect them through services like Apple Fitness+ and Apple HealthKit.

EMERGING PLAYERS

- Peloton
- Tonal
- Mirror by Lululemon
- Hydrow
- FightCamp
- Tempo
- Nautilus
- Apple

7TH YEAR ON THE LIST

Smart Kitchens



The Home Connect app integrates control of appliances across manufacturers to create a single hub.

KEY INSIGHT

Smart kitchens are moving beyond apps to control appliances. New technology is helping consumers by planning meals, sourcing groceries, and even performing some of the cooking autonomously.

EXAMPLES

India-based TinyChef acts as an artificial intelligence meal planner and food shopper while also guiding families, step by step, through recipes with its smart speakers. Nosh is an autonomous cooking bot that can cook more than 200 one-pot Indian dishes. Ingredients are loaded into Nosh, which uses an AI-powered camera to monitor the cooking process and add ingredients depending on personal taste. Smart appliances are making our kitchens safer with motion detectors that start a countdown once they sense no one is in the kitchen and then turn off cooking appliances after a set amount of time. The Bosch Home Connect smart kitchen line connects to Nest Protect. If you forget that pizza in the oven and it starts to catch fire, your Nest smoke detector will tell the oven to turn itself off. The Sensate kitchen faucet from Kohler responds to voice: Ask it for three cups of water, and it will automatically dispense exactly the right amount.

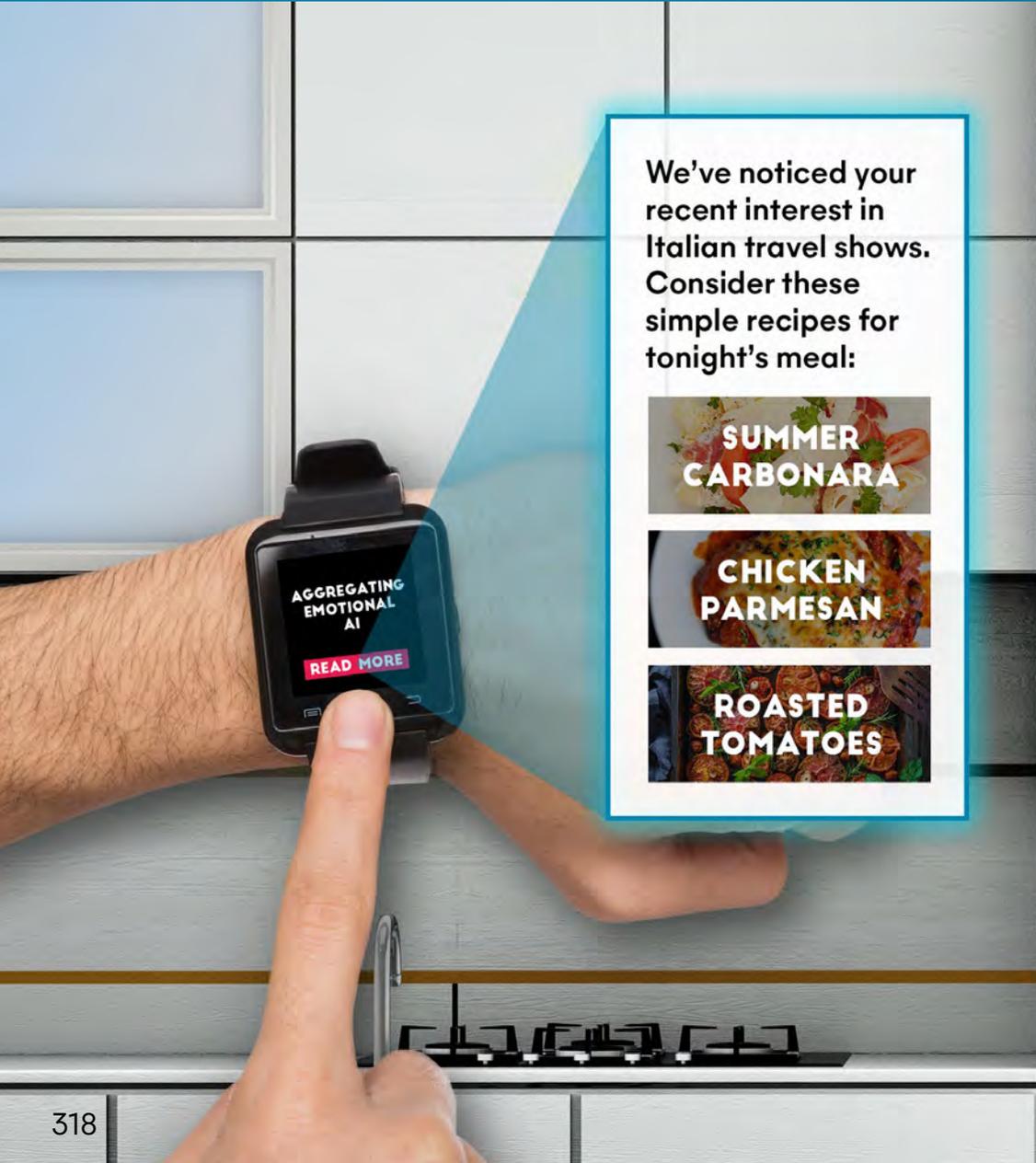
DISRUPTIVE IMPACT

Researchers are advancing networked systems and device handoff protocols designed for the kitchen, creating opportunities for smart appliances and other devices to communicate with one another and work together to streamline efficiencies across the entire network, potentially saving users time, money, and energy. Smart kitchens do more than try to make our lives easier, they also provide manufacturers and tech ecosystems with a deluge of data about habits, tastes, and socializing patterns. This not only deepens understanding of customers but offers insights into windows of opportunity to tweak behavior—such as recognizing that a person hasn't started making dinner yet and offering a free delivery coupon for takeout.

EMERGING PLAYERS

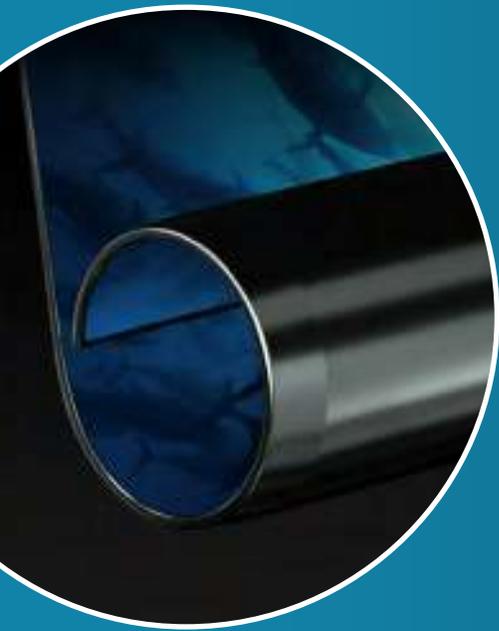
- TinyChef
- Euphotic Labs
- Samsung's Digital Appliance Design Team & Lifestyle Labs
- Google's Design Lab
- LG's Mobile Communications Design Lab
- Amazon Web Services

What To Eat • Mid-future optimistic scenario



2ND YEAR ON THE LIST

Adaptable Surfaces



Flexible, rollable screens are coming to consumer electronics.

KEY INSIGHT

Adaptable surfaces are being developed to bridge the gap between physical and digital interactions, and to bring new utility to familiar devices.

EXAMPLES

Samsung, Motorola, and LG are working on flexible screens for phones and home theaters. Devices include the Motorola Razr 5G, a remake of the supremely popular flip phone from 2006 but with a (literal) twist: The screen folds down and shrinks the phone to half its size. Chinese electronics manufacturer TCL created a phone and a tablet with a rollable screen. A flexible OLED display is tucked away inside the device, and a motor expands the chassis to reveal a larger screen. Users pull the phone to expand it, effectively doubling the screen real estate. LG is developing a suite of rollables, including televisions and a phone. Its rollable OLED TV is already in the market. Interactive projectors like those from Epson and Sony use a short throw lens—to turn walls into interactive surfaces that can be manipulated in real time. They are typically used in educational settings where people can interact with slides and write on whiteboards.

DISRUPTIVE IMPACT

If screens can be anywhere and transform into different shapes, then experiences can grow and adapt to a consumer’s surroundings or circumstances. This will shift UI and UX design in the coming years. Much of the initial slate of adaptable surfaces is in the concept stage—but with this paradigm shift companies are rushing to invent and patent new form factors and uses. For example, Oppo—which made a smartphone with a continuously variable OLED display that automatically adjusts the aspect ratio of what’s being viewed—applied for 122 patents already. Adaptable surfaces will continue to evolve, with components shrinking over time. In the future, this could mean rollable smartphones the size of pencils, and home theaters that can stretch to envelop all four walls of a room.

EMERGING PLAYERS

- Epson
- Sony
- Samsung
- TeamLab
- Oppo
- TCL
- LG



1ST YEAR ON THE LIST

Sleep Tech



Consumers are investing in technology, like the Eight Sleep system, to counter a growing epidemic of sleep deprivation.

KEY INSIGHT

New technologies promise to optimize sleep, even in challenging circumstances.

EXAMPLES

Amazon and Google both received clearance from the U.S. Federal Communications Commission to develop devices with radar sensors that facilitate contactless sleep tracking and record snoring, interruptions, and respiration. South Korean startup Asleep will use passive Wi-Fi for its contactless sleep monitoring system. Last year, Eight Sleep raised \$86 million in a Series C round for its smart, thermostat-controlled mattress, while Bryte announced it will license its sleep technology to traditional mattress makers. The Somnox Sleep Robot is an adaptive pillow to help people steady and deepen their breathing rate. The Sunrise sleep monitor tracks snoring and fitful sleeping—and can help diagnose sleep apnea—using a small sensor that fits on the chin.

DISRUPTIVE IMPACT

We spend about a third of our lives sleeping. The average adult needs between seven and nine hours of good quality sleep every night, according to the Mayo Clinic—but a variety of factors, ranging from anxiety and stress to noisy streets or a partner who snores can interrupt sleep cycles. Tech companies, backed by eager investors, aim to help optimize sleep using sensors, microphones, and artificial intelligence. U.S. patents have increased an average of 12% every year in the past decade, and current estimates put the total market size of sleep tech above \$30 billion by 2026.

EMERGING PLAYERS

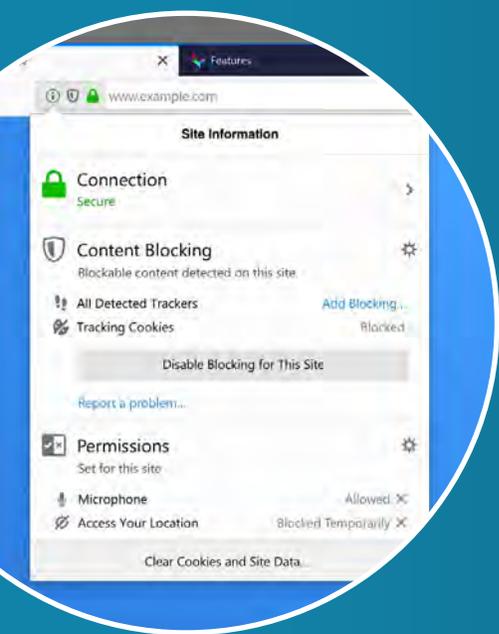
- Beddr
- Bryte
- Eight Sleep
- Asleep
- Onera Health
- ChiliSleep
- 10Minds
- Somnox
- Sunrise
- Dreem

3RD YEAR ON THE LIST

Smart Home Digital Emissions

KEY INSIGHT

Companies are under pressure to curb their CO2 emissions. Smart homes contribute to climate change, too, in the form of digital emissions.



Mozilla Firefox's Enhanced Tracking Protection blocks third-party trackers.

EXAMPLES

All of the technology powering a smart home requires significant infrastructure: wireless or wireline connectivity, cloud computing, electricity, and physical data centers. While much of this infrastructure is invisible to consumers, our smart devices don't work properly without it. The actual energy used when you read a Reddit post or order more toilet paper is extremely small; only a few grams of carbon dioxide are emitted each time. But consider the scale: Billions of people every day each complete dozens (or hundreds) of actions online. The carbon footprint of our devices, the internet, and the data centers we require account for 1.4% to 3.2% of our global greenhouse gasses.

DISRUPTIVE IMPACT

As smart homes proliferate, so too will their digital emissions. Some companies are already working to curb digital emissions. For example, Mozilla Firefox's Enhanced Tracking Protection blocks third-party trackers while cutting energy usage when a consumer is online. It also employs search recycling: If someone types in the search bar to navigate to a site, it requires data processing and energy consumption. Using auto-complete, rather than manually typing, to navigate back to an intended destination means zero-carbon searching. Smart home tech impacts a company's environmental, social, and governance efforts—which means that we can expect novel changes to curb digital emissions in the years to come.

EMERGING PLAYERS

- Mozilla
- ICTFootprint.eu
- Amazon Web Services
- Google
- Apple

If every adult in the United States sent one less email a year, we could save 51,560 tons of CO₂—the equivalent of taking 11,217 gas-powered cars off the road.

6TH YEAR ON THE LIST

Retrofitting Old Homes With New Technology



Nest thermostats are a first step in retrofitting HoT devices into older homes.

Image credit: Google

KEY INSIGHT

As smart home devices become more ubiquitous and affordable, consumers need to retrofit old homes with new technologies.

EXAMPLES

Consumers may already be living in the home of the future. Retrofitting the walls with conduit and cables, embedding surfaces with sensors, and deploying connected appliances and gadgets are ways to modernize existing homes, with results leading to improved energy efficiency, automation of everyday tasks, and new insights from the data your household generates. Often, consumers purchase smart home gadgets first, without considering a whole-home platform. Consumers may buy a \$500 pair of Nest thermostats and then realize the devices can become a building block for the rest of a Google-driven smart home. That purchase may then dictate which platform provider they use going forward: Google, which owns Nest. Manufacturer Honeywell, startup Tado, Apple, and Amazon are also creating their own gateway products for larger home ecosystems.

DISRUPTIVE IMPACT

The more technologies built into smart home systems and appliances, the more potential for things to go wrong—which means that in the near future, we should see new consumer demand for smart home repairs and for service companies with knowledge of how devices connect to the home network and to each other. For now, many systems require a strong cabled internet system to work properly. That could change as 5G networks become more prevalent, enabling smart home technologies to work wirelessly without latency issues.

EMERGING PLAYERS

- Amazon Alexa
- Google Home
- Samsung SmartThings Hub
- HomeOS
- Ecobee
- Philips Hue
- Lutron
- Hunter Douglas

6TH YEAR ON THE LIST

Right to Repair

KEY INSIGHT

Appliance manufacturers build products with intentionally limited life spans, forcing consumers to use their own costly repair services or continually buy new products. Lawmakers are enacting “right to repair” legislation in response.



Apple recently launched its Self Service Repair for users.

Image credit: Konstantin Yolshin/Shutterstock.

EXAMPLES

Modern game consoles, mobile phones, e-readers, microwaves, refrigerators, washing machines, and even hospital ventilators are designed to limit repairs. That’s why consumer activists in the European Union and United States mounted legal action, spurring lawmakers to create laws that would force manufacturers to allow repairs, interchangeable parts, and common standards. In 2021, President Biden signed an executive order directing the U.S. Federal Trade Commission to draft new legislation that would limit manufacturers’ ability to restrict independent repairs of their products. The E.U. also voted in favor of rules to make it easier to repair smartphones, tablets, and laptops, and require products to be supported for at least a decade. At the end of last year, Apple announced its Self Service Repair program: Customers can purchase Apple parts and tools to repair iPhone 12 and 13.

DISRUPTIVE IMPACT

Forcibly bricking our devices raises thorny questions about how hardware and software interact and how companies can responsibly sunset their products. For example, if a company retires an operating system for its smart refrigerator, should consumers still be allowed to continue to use the refrigerator function to keep their food and drinks chilled? If not, they’d have to throw it away. This creates mountains of environmental waste—and with new sustainability mandates going into effect in many countries, “right to repair” laws are likely to gain traction in 2022.

EMERGING PLAYERS

- U.S. Federal Trade Commission
- European Parliament
- U.S. Public Interest Research Group
- UFC-Que Choisir
- Apple

4TH YEAR ON THE LIST

Securing the HoT



Smart devices may simplify our daily lives, but device vulnerabilities are making our homes easy targets for cyberattacks.

KEY INSIGHT

The Home of Things (HoT) has created a broad attack surface for our homes. However, many consumers do not take any measures to protect their connected homes against attack.

EXAMPLES

In April 2021, Forescout Research Labs exposed NAME:WRECK, a set of domain name system (DNS) vulnerabilities that could lead to a denial-of-service (DoS) or remote code execution. This would allow attackers to either take control of smart home devices or block them from connecting to the internet. In August, cybersecurity company Mandiant disclosed vulnerabilities found in Through-Tek's Kalay network. Devices on the Kalay platform—including smart locks, voice assistants, IP cameras, and baby monitors—could be compromised to enable remote control of devices and access to live audio and video feeds. The discovery was just the latest warning in a barrage of HoT security flaws. Despite the risks, consumers are continuing to buy smart devices for their homes—without safeguarding them from outside attackers. Less than 30% of consumers are worried about HoT device security, according to a 2021 Statista survey. This may be one reason why many firmware updates and software patches are delayed or never installed.

DISRUPTIVE IMPACT

One-fifth of all households across the globe will live in smart homes by 2025. If not secured, these smart devices may be compromised by hackers, allowing them to access entire home networks, including laptops, smartphones, and tablets. The Matter interoperability standard introduces new requirements for over-the-air software and firmware updates, and some manufacturers are increasingly relying on blockchain to track and authenticate device security. This isn't the first use of blockchain in HoT security. In 2019, South Korean mobile carrier KT launched GiGA Chain, a 5G-based blockchain platform, which included technology to mask IP addresses of devices and reduce their probability of being targeted. As smart homes become commonplace, security may become a growing subscription service opportunity.

EMERGING PLAYERS

- Matter
- KT
- Mandiant
- Security and Privacy in the Lifecycle of IoT for Consumer Environments (SPLICE)
- National Institute of Standards and Technology
- Black Hat USA

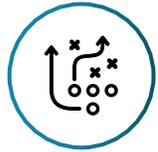


“I think we’ve reached a point where smart home control is expected in new home construction. It is no longer a novelty but rather a proven feature that home buyers want in their new home...We find our home buyers want solutions that are open platforms and extend beyond just controlling lights and locks and the most common smart home features. They also want to integrate control of their televisions and distributed audio systems, so we make sure that we are able to provide that level of control.”

— Felicia Ratka, president of Toll Brothers Smart Home Technologies



How these trends impact your company



STRATEGY

Regulators are targeting Home of Things (HoT) platforms and original equipment manufacturers. Forced obsolescence is under scrutiny from government agencies in several countries, and “right to repair” laws will go into effect this year. This will undoubtedly have a downstream effect on consumer electronics manufacturers and platform providers, as well as others within the developing ecosystem, including internet service providers and mobile network operators, cable companies, and cloud providers. It’s time to rethink interoperability. Strategy teams should model plausible outcomes for the next three to five years and develop alternative business models and pricing strategies.



INNOVATION

HoT platforms are intended for general use—which means that everyone living in a shared space must agree on the settings. Innovation teams can develop personalized use cases and models. For example: What if a coffee machine connected to a smart bed brewed a cup of coffee based on how well you slept? And then an hour later, brewed a custom cup for your partner? As living spaces and the people living in them become more deeply connected, there will be new opportunities for deep personalization.



R & D

The early business cases for HoT devices were positive, which means that an ecosystem is starting to develop in earnest. R&D teams and designers can connect the dots between emerging technologies, network connectivity, and evolving consumer behavior to create the next generation of smart home products. There is much to build, from user interfaces to gadgets that cross a very wide range of ages. Securing the HoT and enabling easier connectivity should be foregrounded. So, too, should power: What happens to the HoT if the power goes out and consumers don’t own battery backups or generators?



GROWTH

As the HoT ecosystem grows to include many more OEMs, device form factors, and use cases, there will be positive and negative knock-on effects. Some families will gain access to a bevy of gadgets created to optimize their lives—while other families may be vulnerable to trading data or family privacy to access technology. Likewise, if devices are not built to last, they will contribute to e-waste. Organizations should decide not just how to play and win in the HoT but how to grow meaningfully. Aligning HoT strategy with company values will be key—and regulators are watching.

Key Questions

We recommend using this report to support your strategic foresight activity in the coming year. Every executive team should begin by asking these questions:

1

- ▶ How does the Home of Things unlock new opportunities for our company?

- ▶ How might we play a role in shaping regulations and policy related to the HoT (right to repair, interoperability protocols, cybersecurity standards) and our industry's evolution?

2

- ▶ What new competitors or adversaries will emerge as the HoT evolves?

- ▶ How could new form factors, platforms, and appliances threaten our business models?

3

- ▶ How does the HoT further the digital divide? What role should our company play in making sure the HoT is inclusive?

- ▶ Does the evolution of the HoT align with our company's ESG goals?

- ▶ How can we ensure that the HoT ecosystem grows responsibly?

Selected Sources

<https://fortune.com/2021/04/21/ai-carbon-footprint-reduce-environmental-impact-of-tech-google-research-study/>

<https://www.computerweekly.com/feature/APAC-datacentres-gear-up-for-the-future>

<https://www.sciencedaily.com/releases/2021/08/210805141154.htm>

<https://techwireasia.com/2021/08/cloudflares-goal-to-power-the-internet-with-zero-emissions/>

<https://source.wustl.edu/2021/08/connective-issue-ai-learns-by-doing-more-with-less/>

<https://www.weforum.org/agenda/2021/03/internet-carbon-emissions-data-path-scion/>

<https://www.techrepublic.com/article/how-edge-computing-can-help-save-the-environment/>

<https://www.zdnet.com/article/googles-deep-learning-finds-a-critical-path-in-ai-chips/>

<https://doi.org/10.1007/s12053-021-09947-y>

<https://www.digitaltrends.com/home/4-reasons-to-look-forward-to-apple-homekit-matter-collaboration/>

<https://www.schlage.com/blog/categories/2021/01/robots-for-home.html>

<https://projectorsavvy.com/interactive-projector-explanation/>

<https://www.wsj.com/articles/smart-speakers-go-beyond-waiting-to-be-asked-11620640802>

<https://www.apple.com/newsroom/2021/11/apple-announces-self-service-repair/>

<https://global.bowflex.com/>

<https://www.nautilusinc.com/brands/>

<https://www.nytimes.com/2021/07/16/nyregion/nyc-mesh-community-inter-net.html>

<https://durabilitymatters.com/planned-obsolescence/>

<https://appletoolbox.com/siri-multiple-people/>

<http://www.theguardian.com/technology/2021/may/17/how-apples-airtag-turns-us-into-unwitting-spies-in-a-vast-surveillance-network>

<https://www.cnet.com/home/smart-home/amazon-sidewalk-will-create-entire-smart-neighborhoods-faq-ble-900-mhz/>

<https://apnews.com/article/self-cleaning-elevator-coronavirus-46ede0867f4be349779fa379545f8c4e>

<https://www.usnews.com/news/health-news/articles/2020-12-03/do-self-cleaning-elevator-buttons-really-work>

https://www.theregister.com/2021/05/18/samsung_bets_on_rollable_and/

<https://www.macobserver.com/columns-opinions/editorial/does-apple-need-get-more-into-homekit-hardware/>

<https://www.menshealth.com/fitness/a35686797/gyms-after-covid-19-pandemic/>

<https://nextcity.org/daily/entry/europe-is-guaranteeing-citizens-the-right-to-repair>

<https://www.idropnews.com/news/faq-can-you-use-apples-airtags-with-old-iphones-well-yes-and-no/157751/>

<https://www.businesswire.com/news/home/20210422005847/en/Global-Smart-Home-Gym-Equipment-Market-2020-to-2026---Key-Motivators-Restraints-and-Opportunities--ResearchAndMarkets.com>

<https://www.wired.com/story/biden-executive-order-right-to-repair/>

<https://www.engadget.com/google-smart-home-io-2021-matter-nest-android-000026115.html>

<https://9to5mac.com/guides/gymkit/>

<https://www.itonlinelearning.com/blog-history-iot/>

<https://spectrum.ieee.org/home-robot-control-for-people-with-disabilities>

<https://appleinsider.com/articles/21/06/07/homekit-enhancements-include-home-keys-share-play-and-new-matter-interoperability-standard>

<https://www.imore.com/multi-user-support-homepod-opens-access-siri-shortcuts>

<https://muninetworks.org/content/how-san-rafael-california-built-neighborhood-mesh-network-turned-something-more>

<https://www.digitaltrends.com/home/how-to-add-multiple-users-to-google-home/>

Selected Sources

<https://www.macworld.com/article/233707/in-2020-apple-is-poised-to-push-homekit-forward.html>

<https://www.globenewswire.com/news-release/2021/04/15/2210905/0/en/Home-Fitness-Equipment-Market-to-Reach-USD-14-74-Billion-in-2028-Introduction-of-Smart-Treadmills-to-Boost-Growth-reports-Fortune-Business-Insights.html>

<https://www.benq.com/en-us/business/projector/interactive-classroom-projectors.html>

<https://doi.org/10.1371/journal.pone.0221854>

<https://www.runnersworld.com/gear/a35688543/workout-mirrors-for-runners/>

<https://www.cnbc.com/2021/04/21/apple-airtag-relies-on-massive-iphone-installed-base.html>

<https://www.ft.com/content/0ba6e2b-bce9-4153-8b52-1abf-d6e921a5>

d6e921a5

<https://electrek.co/2021/01/13/hepa-air-filters-kill-covid-and-this-affordable-purifier-is-for-cars/>

<https://arstechnica.com/gadgets/2021/01/lg-claims-its-rollable-screen-smartphone-is-coming-early-this-year/>

<https://www.gearpatrol.com/tech/a36178024/iphone-airtag-compatibility-precision-finding/>

<https://www.nycmesh.net/map>

<https://mirror.kustomer.help/#personal>

<https://www.motorola.com/us/smart-phones-razr-gen-2/p>

<https://www.wired.com/gallery/best-robot-vacuums/>

<https://www.nest.com/thermostats/real-savings/>

[https://www.independent.co.uk/life-](https://www.independent.co.uk/life-style/gadgets-and-tech/eu-right-repair-technology-decade-b1809408.html)

[style/gadgets-and-tech/eu-right-repair-technology-decade-b1809408.html](https://www.independent.co.uk/life-style/gadgets-and-tech/eu-right-repair-technology-decade-b1809408.html)

<https://www.calcalistech.com/ctech/articles/0,7340,L-3881916,00.html>

<https://www.inputmag.com/tech/pelotons-tread-is-now-completely-unusable-without-a-subscription>

<https://www.theverge.com/2021/7/15/22578346/pepper-robot-failures-wall-street-journal>

<https://www.bbc.com/news/technology-57744091>

<https://www.indiegogo.com/projects/2552376>

<https://support.apple.com/en-us/HT204753>

<https://www.iotforall.com/smart-home-interoperability-fragmented-landscape>

[https://www.gsma.com/iot/knowledge-](https://www.gsma.com/iot/knowledge-base/spectrum/)

[base/spectrum/](https://www.gsma.com/iot/knowledge-base/spectrum/)

<https://beebom.com/smart-projector-turn-surface-into-touchscreen-android-tablet/>

<https://borderless.teamlab.art/>

<https://futurepark.teamlab.art/en/>

<https://hiconsumption.com/best-smart-home-gyms/>

<https://electrek.co/2021/01/13/hepa-air-filters-kill-covid-and-this-affordable-purifier-is-for-cars/>

<https://www.vangoghny.com/>

<https://www.kbb.com/car-news/will-my-cars-filter-system-help-reduce-the-spread-of-coronavirus/>

<https://www.runnersworld.com/gear/a35688543/workout-mirrors-for-runners/>

<https://developer.sony.com/develop/xperia-touch/>



Policy, Government & Security

Tech and science trends influencing lawmakers, governing, geopoliticals and cybersecurity.



Table of Contents

333 Key Insights	357 Interoperability Initiatives	378 Critical Attacks	384 Low-Cost Malware
334 Global Innovation and GovTech Advancements	358 Corporate Denial-of-Service (CDoS)	378 Supply Chain Attacks	384 Cyber Risk Insurance
335 Accelerating Government Digitalization	359 Global Tech Policy	378 Zero-Day Exploits Rising	385 Internet Traffic
336 Digital Identity Programs	360 Corporate Foreign Policy	378 Zero-Knowledge Proofs Go Commercial	385 DDoS Attacks on the Rise
337 Scenario: Long Lines at Meta Hall	361 Techno-Nationalism	379 Cyber Policy	385 Hijacking Internet Traffic
338 Accessible Public Data	362 Splinternets	379 Regulating Messy Code	386 Hactivism
339 Digital Dividends	363 Multilateral Science and Technology Acts	379 Global Cybersecurity Pacts	386 Ransomware-as-a-Service
340 Vaccine Passports	364 Vaccine Diplomacy	379 Government Requests for Backdoor Access	386 Decentralized Hacktivists
341 U.S. Government Initiatives	365 Space Diplomacy	380 Remote Kill Switches	386 Proliferation of Darknets
343 (Re)Investing in Basic Research	366 Geoengineering Policy	381 Cyberwarfare	387 Cybersecurity Terms Every Executive Should Know
344 Overhauling Legacy IT	367 Neurorights Campaigns	381 Automated Attacks Using AI	391 Application
345 Federal WFH	368 China Focus	381 State-sponsored Security Breaches	392 Key Questions
346 State and Local Initiatives	370 China's Tech Crackdown	381 Critical Infrastructure Targets	393 Selected Sources
347 Citywide Metaverses	371 Scenario: How To Stream Game of Thrones Re-Finale	382 Offensive Government Hacking	
348 Mesh Networks	372 China's Quest for Cyber Sovereignty	383 Safeguarding the Home of Things	
349 State Charters for Blockchain	373 Security	383 WFH Security	
350 State Governments Tackle Digital Privacy	374 A very brief list of 2021 attacks and breaches	383 Consumer IoT Vulnerabilities	
351 States Regulate Biometric Data	377 Bio-Cyberattacks	383 Sonic Lock Picking	
352 Local Autonomous Vehicle Regulations	377 COVID-Related Hacking	384 Corporate Security and Espionage	
353 Government vs. Big Tech	377 Biometric Malware	384 Bounty Programs	
354 Antitrust	377 DNA Database Hacks	384 Data Theft Becomes Data Manipulation	
355 Data Ownership	377 Cyber Homicide		
356 Cloud Neutrality			

Key Insights

- * Cities are breaking ground on public metaverses—sparking a new need for “digital” city planning.
- * As neurotech moves from labs into trials, some governments are banning the collection and sale of brain data.
- * Digital IDs will start outpacing physical ID use in 2022.
- * The Caribbean nation Barbados hopes to develop what it calls “digital sovereign land” and virtual embassies that would rely on a digital identity system.
- * Biometrics used alongside cloud-based identity management systems will lead to more ubiquitous contactless biometric authentication.

- * Ransomware will become the new “smash and grab” of cybercrime.
- * Security teams will need to be more proactive with zero-trust security, vendor security assessments, internal monitoring, and IT/OT convergence.
- * A handful of companies control the cloud and have the sole ability to set pricing, access, and standards. A concentrated market for an invaluable service creates high risk.
- * This could be a seminal year for tech regulation, after several years of lawsuits, regulatory fines, and legislative efforts.
- * Neighborhood mesh networks could pose a competitive threat to wireline cable and internet service providers, and upend their business models.

- * No longer waiting for federal guidance, state governments are now developing rules and regulations for data privacy protections.
- * Likewise, cities and states are also developing their own regulations for autonomous vehicles and ways to integrate them into city planning.
- * 75% of businesses do not involve their boards of directors in cybersecurity oversight.

CHINA FOCUS

- * COVID-19 has offered China an opportunity to exert its influence through the distribution of vaccines and medical aids. But help frequently comes with strings attached.

- * China is working to make its space research, equipment, and artifacts available to foreign researchers, as part of a broader diplomatic effort.
- * Beijing has hundreds of basic research projects underway, ranging from new quantum systems and supercomputers to synthetic biology and genetic engineering.
- * The Chinese government is cracking down on its largest tech companies, citing anticompetitive behavior and regulatory infractions. The reason likely has to do with an interest in focusing tech development to align with national priorities.
- * New technologies promise to stabilize climate change, but they could damage international relations. This year, new solar geoengineering trials will take place.



00

01

02

03

04

05

06

07

08

09

10

11

12

13

Policy, Government & Security

Global Innovation & GovTech Advancements

1ST YEAR ON THE LIST

Accelerating Government Digitalization



Singapore developed a cloud-based communications service to make government agencies more efficient.

KEY INSIGHT

The global pandemic accelerated digital transformation. From automating city services to the acceptance of telehealth, new modernization initiatives are being deployed across local, city, state/provincial, and national governments. This sets the stage for the long-term digital transformation of government administration.

EXAMPLES

The cloud enables more government employees to work remotely and securely, and it is enabling agencies to share valuable insights across departments. Singapore developed its Postman service, a cloud-based communications tool now used by various local agencies—including its Ministry of Education and Ministry of Health—to message citizens. In the U.S., the Internal Revenue Service, Department of Veterans Affairs, and Department of Housing and Urban Development all deployed robotic process automation to meet demand for labor-intensive services. In emerging markets, the Digital Impact Alliance is helping governments build and scale digital government programs. One of its first projects: collaborating with the Smart Africa Alliance, a partnership of 32 African countries working on implementing government digital systems that don't require a capital-intensive upfront investment.

DISRUPTIVE IMPACT

In the next several years, governments will invest in updating government systems and bolstering digital infrastructure. The government of Spain announced a \$22 billion investment to accelerate digitalization and a public-private partnership worth \$62 billion. In Italy, the government approved \$2.25 billion for a digital overhaul of the health care system. The U.S. government approved \$65 billion for a nationwide broadband upgrade.

EMERGING PLAYERS

- NextGenerationEU
- U.S. Robotic Process Automation Community of Practice
- The Commission for Smart Government in the U.K.
- U.S. Digital Service
- Digital Impact Alliance

1ST YEAR ON THE LIST

Digital Identity Programs



KEY INSIGHT

Digital identity systems authenticate citizens and enable them to interact with their government and its private sector partners. These systems allow people to securely and privately assert their identities as needed, and they are growing in popularity.

SecureKey is a blockchain-backed digital identity system operating in Canada.

EXAMPLES

Digital ID systems are already in place in a few countries. Canada's SecureKey is a blockchain-backed identity system used to broker trusted interactions between financial institutions, governments, and telecommunications network operators. Citizens can connect to various online services using one digital credential. For banks, digital ID can reduce fraud, improve security and the protection of customer data, streamline authentication, and facilitate automated transactions. In Estonia, all citizens, regardless of where they live, have a state-issued digital identity. The European country deployed its electronic identity program, called e-ID, some two decades ago. The government of Ontario, Canada, announced the launch of its digital ID program in 2022, while this year the European Commission is reviewing a digital ID for all European Union member citizens. In the U.S., a national digital ID bill will be debated in 2022.

DISRUPTIVE IMPACT

A billion people worldwide lack a legally recognized form of identity, which prevents them from receiving needed services. Meanwhile, as people adopt a multitude of digital personas for use in online communities and the metaverse, they'll need new forms of authentication to facilitate trusted interactions, e-commerce transactions, and even basic tasks, like verifying relationships.

EMERGING PLAYERS

- Digital Identity Alliance
- Digital ID & Authentication Council of Canada
- Rep. Bill Foster (D-Ill.) and Rep. John Katko (R-N.Y.)
- National Institute of Standards and Technology
- Illinois Department of Innovation and Technology
- Government of Ontario

Long Lines at Meta Hall · Near-future pessimistic scenario

Long Lines at Meta Hall

At Springfield's Metaverse City Hall, our city officials are ready to meet with you. Behind every avatar is a real person, who can answer your questions about your water bill, property taxes, and other city services. You can also chat with them to learn more about our exciting city's history, event venues, and community spaces. Welcome!



Message From Springfield City Hall's Community Manager

Hello Springfield Citizens!

Hi. I'm Fiona from City Hall. All of our representatives are currently busy with other citizen avatars. Our current wait time is 270 minutes.



1ST YEAR ON THE LIST

Accessible Public Data



The city of Amsterdam operates a data exchange to facilitate interactions between government, citizens, businesses, and researchers.

KEY INSIGHT

Public agencies are pooling and standardizing data, making it interoperable and reusable across government departments and the private sector.

EXAMPLES

The Amsterdam Data Exchange, built in partnership with the city of Amsterdam, acts as a trusted intermediary between government agencies, citizens, businesses, and researchers to safely share information. In Singapore, a national platform makes it easy for citizens to securely upload their personal data using one universal form, which can then be accessed—only when needed and when permission is granted by the individual—by outside institutions such as mortgage lenders. The U.S. National COVID Cohort Collaborative allows government agencies, scientists, and researchers to store, share, and access clinical data.

DISRUPTIVE IMPACT

COVID-19 accelerated the demand for usable data across the public sector. Before the pandemic, data was often siloed intentionally, or unintentionally (due to lax standardization). Monitoring the spread of SARS-CoV-2 and its variants and understanding its impact on communities led to a change of heart. Many governments are now reviewing their data collection and governance strategies, they are redefining their data quality standards, and they are building new systems to encourage collaboration.

EMERGING PLAYERS

- Australian Data Exchange
- Amsterdam Data Exchange
- Cambodia Data eXchange
- National COVID Cohort Collaborative
- National Institute of Standards and Technology
- Netherlands' Ministry of Health, Welfare, and Sport

6TH YEAR ON THE LIST

Digital Dividends



California Gov. Gavin Newsom, who has proposed a digital dividend, won a recall election in the fall of 2021.

Photo credit: Jana Asenbrennerova/
Shutterstock.com.

KEY INSIGHT

A digital dividend would give citizens a cut of the profits derived from their personal data.

EXAMPLES

Proponents of a universal basic income (UBI)—which would give every person a tax-free, flat amount of income regardless of employment or wealth status—say it would help offset the effects of automation, advanced robotics, and artificial intelligence on the market for human labor. Once a fringe socioeconomic concept, UBI is emerging as a solution to ongoing uncertainty in the labor market—but instead of sending regular payments, some are advocating for a new kind of digital dividend. In 2019, California Gov. Gavin Newsom proposed a “data dividend” that would pay state residents for access to their digital data. Additional examples include national data trusts and blockchain-backed data exchanges.

DISRUPTIVE IMPACT

The tech giants currently monetize user data as a significant portion of their revenue. A national data trust would enable public and private organizations to similarly harness consumer data at a cost—profits would then be evenly distributed to citizens. An alternative is a blockchain-backed exchange, which would deliver a small percentage of advertising revenue into a pool that’s later distributed as part of a UBI program.

EMERGING PLAYERS

- Stanford Center on Philanthropy and Civil Society
- Sir Tim Berners-Lee’s Solid initiative
- MyData

2ND YEAR ON THE LIST

Vaccine Passports



International certifications proving COVID-19 vaccination or negative test results are increasingly required to travel.

KEY INSIGHT

Proof of a COVID-19 vaccine is increasingly required to cross borders, enter public buildings, and dine in restaurants. But standardization is lacking, making it challenging for people traveling between some states and countries.

EXAMPLES

As we enter year three of the pandemic, many countries have rolled out a digital vaccine authentication system. The European Union launched its Digital COVID Certificate (formerly called the Digital Green Certificate), which is now used to facilitate proof of vaccine status. Within the European Union, certificate holders are not required to take tests or quarantine to enter countries. While U.S. lawmakers spent 2021 debating a national verification program, some communities enacted laws to ban local vaccine passports requirements, and some states launched their own programs. New York deployed its Excelsior Pass, which shows both digital vaccination records and negative test results of state residents. California operates a Digital COVID-19 Vaccine Record portal and app, which patrons use before entering venues.

DISRUPTIVE IMPACT

SARS-CoV-2 is likely to be with us for many years to come, including efforts to curb the spread of the virus. What's needed in the long term: vaccine passport standardization and interoperability. Some startups are already innovating to make digital passports easier to use. Swedish startup Dsructive Subdermals developed a tiny implantable chip—2 mm x 16 mm—that displays the EU Digital COVID Certificate when pinged.

EMERGING PLAYERS

- European Commission
- U.S. Centers for Disease Control and Prevention
- California Health and Human Services
- Key to NYC Pass
- Clear's Health Pass



00

01

02

03

04

05

06

07

08

09

10

11

12

13

Policy, Government & Security

U.S. Government Initiatives



The science behind climate change is not a hoax. The science behind the virus is not partisan. The same laws apply, the same evidence holds true regardless of whether or not you accept them.

— Kamala Harris, Vice President of the United States



2ND YEAR ON THE LIST

(Re)Investing in Basic Research



KEY INSIGHT

Facing lingering pandemic impacts, new threats posed by climate change, and a shift in geopolitical tensions, governments are investing once again in basic research.

In February, President Joe Biden announced that Dr. Alondra Nelson will perform the duties of director of the White House Office of Science and Technology Policy (OSTP) until permanent leadership is nominated and confirmed.

Image credit: Dan Komoda

EXAMPLES

Beginning in the late 1960s, the federal government has ceded its share of basic R&D to the private sector. Basic research is characterized as experimental or theoretical work undertaken to acquire new knowledge of an emerging area of science or technology. While the foundations of artificial intelligence were primarily funded through government grants in the 1960s, today the frontiers of deep learning and other advanced AI technologies are funded through publicly traded companies like Google, Facebook, and Amazon. This creates tension between researchers, who often want to stay heads-down and work, and shareholders, who want practical, applied outputs and products in the marketplace. However, as China starts to surpass the U.S. in government-funded basic research, the U.S. and other governments now see basic research as a path to enhance competitiveness.

DISRUPTIVE IMPACT

Beijing has hundreds of basic research projects underway, ranging from new quantum systems and supercomputers to synthetic biology and genetic engineering. China has restructured its higher education system to position universities to conduct basic research at scale. Canada's New Frontiers in Research Fund will award \$144 million for research projects over the next six years. While the Biden administration has made the Office of Science and Technology Policy a Cabinet-level agency and nominated well-known scientists to the President's Council of Advisors on Science and Technology, a long-term strategic plan to fund the creation of new technologies and science is required to remain globally competitive.

EMERGING PLAYERS

- China's National Basic Research Program
- China's National High-Tech R&D Program
- China's Ministry of Science and Technology
- François-Philippe Champagne, Canada's minister of innovation, science, and industry
- Canada's New Frontiers in Research Fund
- German Research Foundation
- Max Planck Society
- Helmholtz Association
- Leibniz Association
- National Science Foundation
- Office of Management and Budget

5TH YEAR ON THE LIST

Overhauling Legacy IT



KEY INSIGHT

Parts of the federal government rely on comically old technology that is very difficult to maintain. Many government IT systems worldwide haven't been updated since they were originally built. However, overhauling legacy infrastructure is now a priority.

Legacy IT equipment is expensive to maintain. This year could finally bring needed upgrades to some government agencies.

EXAMPLES

Last year it took five months to issue \$1,200 stimulus checks to eligible taxpayers because IRS computer systems, built in the 1970s, couldn't be easily reconfigured. A sobering tech audit found that the U.S. State Department tracks visa information for 55,000 foreign nationals using a 26-year-old system that's been decommissioned by the software maker. Upgrading a legacy system would cause major disruption, and government offices, already strapped for personnel, don't have easy workarounds. Because the systems are taxpayer funded, government agencies tend to underinvest, avoid maintenance, and cut corners on upgrades to save money. Few technicians have enough institutional knowledge to make the necessary fixes, which means rehiring retired employees at high contract wages.

DISRUPTIVE IMPACT

The U.S. Government Accountability Office has prioritized 10 critical federal legacy IT systems that need modernization, are expensive to maintain—at a cost of \$337 million annually—and rely on obsolete languages, such as COBOL. Only two federal agencies have documented plans to address system upgrades. As of early 2022, there was bipartisan support to modernize critical legacy systems, which could do more than mitigate security risks. Upgrading a government's digital infrastructure could evolve into a virtuous cycle of investment, job creation, economic growth, and much-needed innovation throughout the public sector.

EMERGING PLAYERS

- Senate Homeland Security and Government Affairs Subcommittee on Emerging Threats and Spending Oversight
- U.S. Government Accountability Office
- United States Digital Service
- Office of Management and Budget
- Office of Science and Technology Policy

1ST YEAR ON THE LIST

Federal WFH



Federal employees will continue to work in hybrid environments, with some teleworking and some commuting to offices.

KEY INSIGHT

The federal government is developing plans for permanent hybrid work from home policies, which will allow employees to split their time between being in the office and teleworking.

EXAMPLES

When the pandemic first struck, the federal government enacted policies to allow employees to work remotely in an effort to keep government systems and agencies running. In 2021, the Biden administration determined that a “work from anywhere” policy—for certain roles—would be a key future driver in its ability to attract and retain talented employees. This plan hints at post-COVID “maximum telework flexibilities” for nearly 2.1 million federal employees, as well as the sprawling network for federal contractors.

DISRUPTIVE IMPACT

Facing competition from private companies that offer higher salaries and more enticing perks, the Biden administration is asking federal agency heads to rethink their current staffing structures—and to imagine alternative future workplaces where employees could work together when needed but from their own home offices or other locations as well. This changes the government’s long-standing strategy for building occupancy, which could shrink spending. While digitalization could enable remote work to scale, agencies will need to calibrate IT infrastructure and computer equipment to ensure that connections are secure—and they will need to track performance and productivity without making employees feel continuously watched. Some jobs—such as those at agencies that still rely on paper forms and in-person constituent visits—wouldn’t easily transition to a WFA format.

EMERGING PLAYERS

- American Federation of Government Employees
- House Oversight and Reform Subcommittee on Government Operations
- Office of Personnel Management
- Professional Managers Association



State & Local Initiatives

1ST YEAR ON THE LIST

Citywide Metaverses



When Seoul announced its plans to develop a city-scale metaverse, Seoul Mayor Oh Se-hoon made the announcement as an avatar. Image credit: Seoul city government.

KEY INSIGHT

When tech companies made bold announcements about their shift into decentralized technologies and the metaverse, some cities broke (digital) ground on new infrastructure and city services. Think of it as “digital city planning.”

EXAMPLES

The South Korean capital, Seoul, is developing a citywide metaverse platform this year. It’s an early example of a public metaverse that will offer city services and cultural events. The ecosystem will include what digital city planners call the Metaverse 120 Center, a portal for city residents to virtually complete transactions—registering a complaint or notifying city departments that something needs repair—rather than at city hall. Several cities in China are building public metaverses, including Shanghai, which included the development of a public metaverse in its five-year plan. In the U.S., the Downtown Santa Monica District is building a public metaverse primarily for entertainment and tourism.

DISRUPTIVE IMPACT

While the metaverse is still being developed, some governments are already starting to push the boundaries of what citizens might do in virtual environments. The Caribbean nation Barbados is hoping to develop what it calls “digital sovereign land” and virtual embassies. If it succeeds, Barbados would use a digital identity system allowing citizens to transport their avatars from one virtual world to another through those virtual embassies.

EMERGING PLAYERS

- Samsung
- Facebook (Meta)
- Decentraland
- Metaverse Group
- SuperWorld

Think of public metaverses as enormous, digital city planning projects.

3RD YEAR ON THE LIST

Mesh Networks



Participants of NYC Mesh want to create a freely accessible, wireless community network via their interconnected routers.

KEY INSIGHT

For many years creating a network for exchanging specific types of data was something reserved for the highly technical or for large corporations. Today, advances in networking technology and lower barriers to entry are enabling the buildout of purpose-designed networks at the neighborhood level and for the average person to be an active part of their local network infrastructure.

EXAMPLES

Amazon developed a mesh network protocol for Internet of Things devices it calls Amazon Sidewalk. The protocol is built into all of Amazon's new IoT devices and uses Bluetooth and 900MHz radio signals to extend the internet connectivity range of smart lights and cameras by up to half a mile. By connecting one device to another to get to the internet, each device that gets added to the network extends the network's range. For consumers, this means the smart lights at the end of your driveway could seamlessly and securely connect to a neighbor's doorbell camera as a gateway to the internet instead of relying on the limited Wi-Fi range coming from the cable modem in a living room. Apple AirTags use a similar mesh network approach by piggybacking on the Bluetooth sensors incorporated into all iPhones. The tags send a unique identifier over Bluetooth that any compatible Apple device will recognize and re-broadcast to Apple's servers.

DISRUPTIVE IMPACT

The popularity of specific use case mesh networks for specific types of data could separate out internet bandwidth to make it more effective for the purpose and need required. Allowing for data to be routed by the path that is most aligned to its needs— instead of all data flowing arbitrarily through a single, overwhelmed router—could significantly improve load balancing of data movement. Piggybacking on existing infrastructure to take advantage of existing install bases is also a rapid way to achieve scale. But scaling with limited customer consent and support will require a delicate balance. Neighborhood mesh networks are currently being built by tech companies—not city governments. This could pose a competitive threat to wireline cable and internet service providers, and upend their business models.

EMERGING PLAYERS

- Apple AirTag
- Amazon Sidewalk
- NYC Mesh
- GSMA

2ND YEAR ON THE LIST

State Charters for Blockchain



Wyoming passed special legislation to allow banks to store cryptocurrency, in a bid to become a U.S. hub for the emerging digital currency ecosystem.

KEY INSIGHT

U.S. states are developing charters and special permissions to stimulate blockchain use for digital identification, cryptocurrencies, and digital asset management.

EXAMPLES

Wyoming became the first state to approve a banking charter for digital assets when it approved applications by Kraken (a consumer-focused cryptocurrency exchange) and Avanti Bank & Trust (a bank created to hold crypto for institutions) to form the first two special purpose depository institutions (SPDIs) in the world. The SPDI permit enables institutions to take deposits and offer custody and fiduciary services for digital assets. All this came to fruition just one year after Wyoming passed legislation to allow SPDI charters. The state's Division of Banking granted permission to Two Ocean Trust, a wealth management services firm, to provide custodial services for digital assets. In 2021, Nebraska and Texas signed laws authorizing state-chartered banks to custody cryptocurrency. Illinois has proposed similar legislation, and New York now offers BitLicenses for virtual currency activities.

DISRUPTIVE IMPACT

Given the success in Wyoming, more states are now considering charters to attract startups and investment. Governments that create burdensome regulations around crypto may find that industry players and the opportunity they bring may leave for greener pastures. That said, federal regulations could nullify state and municipal efforts. The states are eager to court startups, so new policies and regulations favoring blockchain initiatives are likely to evolve.

EMERGING PLAYERS

- Wyoming Gov. Mark Gordon
- Nebraska Gov. Pete Ricketts
- Texas Gov. Greg Abbott
- Illinois Gov. J.B. Pritzker
- U.S. Sen. Cynthia Lummis (R-Wyo.)
- Federal Reserve Board
- Office of the Comptroller of the Currency

2ND YEAR ON THE LIST

State Governments Tackle Digital Privacy



California's Consumer Privacy Act inspired lawmakers in other states to create similar legislation.

KEY INSIGHT

State governments are developing rules and regulations for data privacy protections. In 2022, California will update its consumer privacy statute, which will have a cascading effect throughout many state legislatures.

EXAMPLES

Once California passed its California Consumer Privacy Act (CCPA) in 2018, multiple states began work on similar legislation. As of January 2022, Virginia and Colorado have signed legislation to protect consumer rights, while the state legislatures of Washington, Minnesota, Alaska, New York, Pennsylvania, Ohio, Maryland, Massachusetts, New Jersey, Indiana, and Florida all have bills in committee. In August 2020, Maine's internet privacy law went into effect, exclusively regulating broadband internet access service providers (think Comcast and Verizon). Big law enforcement actions have emerged, too. Vermont's attorney general filed suit against Clearview AI for violating the state's data broker laws.

DISRUPTIVE IMPACT

A patchwork of state regulations is not ideal for consumers or companies, but it underscores to the federal government that there is an appetite for data privacy laws. COVID-19 contact tracing and data breaches of a range of institutions have furthered the privacy discussion. If the federal government doesn't act, tech companies must juggle various nuanced laws across the country. Yet the free market may pick winners and losers. Encrypted messaging app Signal saw explosive growth in 2021 as consumer fears about WhatsApp sharing data with Facebook led to mass user migration. Companies that don't take data privacy seriously will lose market share to privacy-conscious competitors.

EMERGING PLAYERS

- Internet Association
- International Association of Privacy Professionals
- Electronic Frontier Foundation
- National Conference of State Legislatures
- The Uniform Law Commission

2ND YEAR ON THE LIST

States Regulate Biometric Data



States are starting to develop biometric data regulations, including new laws prohibiting facial recognition.

KEY INSIGHT

State governments are developing new policies for using biometric data, with a special focus on how law enforcement uses it.

EXAMPLES

In 2021, several states and cities passed stringent laws preventing the use of facial recognition technology. Baltimore now prohibits the use of the technology by city residents, businesses, and most of the city government, and Maine passed a state ban on the technology entirely. Instead, law enforcement in the state must rely on the FBI and Maine Bureau of Motor Vehicles to run facial recognition searches. Meanwhile, Illinois has some of the strictest biometric privacy laws in the country: It requires public disclosure and consent to biometric screening. Biometric data cannot be collected from Illinois citizens without consent, regardless of where a company or institution is based—and it cannot be sold, transferred, or traded.

DISRUPTIVE IMPACT

While facial recognition technology is up against increased scrutiny in individual states, more advanced biometric systems are being deployed to monitor customers, employees, and students. For example, eye movements can determine whether a student is paying attention during an online class—or whether they are cheating on a test. An employee's movements can be traced to learn how much time they spend with other employees, the frequency of their bathroom breaks, and the like. Only three states currently enforce stringent biometric privacy laws: Illinois, Texas, and Washington, but that could change as consumers become more aware of how third parties collect and use their personal data. Lawmakers must grapple with privacy rights and unauthorized collection of data, as well as with the technology's effectiveness in law enforcement.

EMERGING PLAYERS

- U.S. Department of Justice
- American Civil Liberties Union
- Illinois Attorney General Kwame Raoul
- Texas Attorney General Ken Paxton
- New Jersey Acting Attorney General Andrew Bruck
- New York State Sen. Brad Hoylman
- U.S. Sen. Ed Markey (D-Mass.)

1ST YEAR ON THE LIST

Local Autonomous Vehicle Regulations



Argo AI is partnering with auto manufacturers to bring autonomous ride sharing and package delivery services to U.S. cities.

KEY INSIGHT

As electric vehicles become more sophisticated, adding semi-autonomous or full-autonomous features, local governments must determine when and how to authorize their use within city limits.

EXAMPLES

In 2022, several companies will begin trialing autonomous rides in U.S. cities. Argo AI, in a partnership with Volkswagen and Ford Motor, will offer self-driving rides in Miami and Austin (with a company representative in the vehicle). In Seattle, Zoox—which operates as an independent company inside of Amazon—is testing autonomous rides and developing a new type of passenger vehicle that doesn't have a steering wheel. Local governments and business communities eye autonomous vehicles as an engine for economic growth.

DISRUPTIVE IMPACT

Without intervention by the federal government, cities and states are exploring new ways to integrate autonomous vehicles into their longer-term planning. Several cities, including Phoenix and Los Angeles, are developing innovative approaches to designing, building, and testing autonomous vehicle systems. Several states and cities are considering legislation to help bring autonomous vehicles to market. But regulations intended to spur development could hit a roadblock—city and state governments control their local streets, but the federal government regulates surrounding highways. For autonomous vehicles to become ubiquitous and practical, America's roads would need to be interoperable.

EMERGING PLAYERS

- National Highway Traffic Safety Administration
- U.S. Department of Transportation
- National League of Cities
- Arlington, Va.
- Austin, Texas
- Boston
- Chandler, Ariz.
- Concord, Mass.
- Denver
- Detroit
- Gainesville, Fla.
- Las Vegas
- Lincoln, Neb.
- Mesa, Ariz.
- Pittsburgh
- San Francisco
- Tampa, Fla.
- Seattle



00

01

02

03

04

05

06

07

08

09

10

11

12

13

Policy, Government & Security

Government vs. Big Tech

5TH YEAR ON THE LIST

Antitrust



KEY INSIGHT

This could be a seminal year for tech regulation after several years of lawsuits, regulatory fines, and legislative efforts.

U.S. government agencies announced plans to investigate Big Tech companies in 2022.

Image credit: mundissima/Shutterstock.com.

EXAMPLES

Lawmakers and federal agencies have long expressed antitrust concerns about Big Tech's expanding power, including the companies' ability to control data; their power to impose terms on competitors; their dual role as both platform participants and owners; the potential for algorithms to thwart competition; the giants' habits of infringing on small competitors' patents; and recent merger and acquisition activity that has helped powerful tech interests consolidate even more power. Expect to see closer scrutiny of M&A activity in 2022. Last year, the U.K. ordered Facebook (now Meta) to divest itself of Giphy, a GIF platform it acquired in 2020. Of particular interest in the U.S.: a Federal Trade Commission antitrust probe into Meta's plan to acquire the company behind VR fitness app Supernatural for \$400 million, and the agency's action to block Nvidia from acquiring chip designer Arm for \$40 billion, one of the largest semiconductor deals ever.

DISRUPTIVE IMPACT

In January 2022, Apple became the first company worth \$3 trillion; together with Microsoft, Google, Amazon, and Meta, America's biggest tech companies have a combined value of \$10 trillion. The Biden administration may expand the scope of investigations this year. The FTC is involved in many lawsuits already, which include actions to force Meta to divest itself of WhatsApp. Breaking up Big Tech could prove difficult: Amazon's moves to build digital payments, logistics, and delivery infrastructure could indirectly crush retailers outside its platform—yet it isn't illegal. No U.S. laws prohibit companies from being really, really smart. The European Union's Digital Services Act and Digital Markets Act would require tech giants to protect consumers against illegal goods and counterfeits and would prohibit platforms from algorithmically favoring their own products, with fines as high as 10% of annual revenue. The European Parliament must approve the new reforms before they take effect.

EMERGING PLAYERS

- Margrethe Vestager, European commissioner for competition
- U.S. Sen. Amy Klobuchar (D-Minn.)
- U.S. Sen. Elizabeth Warren (D-Mass.)
- Lina Khan, chair U.S. Federal Trade Commission
- U.K. Competition and Markets Authority
- U.S. Department of Justice's Antitrust Division

No U.S. laws prohibit companies from being really, really smart.

3RD YEAR ON THE LIST

Data Ownership



This year, tech companies will need to answer questions about consumer data—and who is the ultimate custodian of it.

KEY INSIGHT

Tech companies, advocacy groups, and governments are grappling with who should own the rights to consumer data and who has the ultimate power and control over private information.

EXAMPLES

A sprawling data economy underpins our modern world. Dating apps, airline companies, search systems, e-commerce sites, and health care companies rely on consumer data—and often, as this data passes between third parties, it can be impossible to see how and where personal data is traveling. This becomes especially problematic when hackers breach security protocols and gain access to sensitive information, which is happening more frequently. The U.S. uses a patchwork approach to governing data ownership and use, pushing the responsibility to individual states to set privacy standards. In most countries, “data ownership” typically refers to the legal rights to intellectual property or copyrights. But when it comes to who owns consumer data, there are few guidelines—and big implications—for business.

DISRUPTIVE IMPACT

This year, as regulatory scrutiny of Big Tech focuses on antitrust concerns and privacy, lawmakers will begin to address broader questions: Who is the legal guardian of a consumer’s data? Do companies have the right to change end user agreements regarding that data? Instead of ownership, should companies merely be the stewards or temporary guardians of data? What about genetic data? Some answers are emerging: Minimize the amount of data collected; require consumers to opt in and consent to their data being sold or used by third parties; prevent companies from discriminating against people if they exercise privacy rights (i.e., charge them the same rates as people who allow their data to be used); and be transparent about what data is collected and by whom.

EMERGING PLAYERS

- Lina Khan, chair, U.S. Federal Trade Commission
- Rebecca Kelly Slaughter, FTC commissioner
- Kate Ruane, senior legislative counsel, American Civil Liberties Union
- California Attorney General Rob Bonta
- International Association of Privacy Professionals
- Sir Tim Berners-Lee’s Solid initiative
- MIT Trust-Data Consortium

2ND YEAR ON THE LIST

Cloud Neutrality



Cloud providers wield enormous power over the internet.

KEY INSIGHT

A handful of companies control the cloud and have the sole ability to set pricing, access, and standards. Those companies own the infrastructure and don't have to make their business practices transparent. As more of our businesses and lives move to the cloud, efforts will grow to ensure infrastructure serves the public interest.

EXAMPLES

The three biggest cloud providers, Microsoft, Amazon, and Google, have collectively invested tens of billions of dollars building infrastructure: data centers, monitoring systems, and software. These robustly designed systems prevent downtime and data loss, and few other companies in the world can compete. And as private companies, cloud providers currently control access to their services—services that are becoming the lifeblood of businesses. For example, following the Jan. 6, 2021, attack on the U.S. Capitol, Amazon Web Services kicked Parler, the ultraright social platform, off its cloud for violating its terms of service. The decision shows how much influence cloud companies have over the internet. These private companies sometimes compete with the cloud provider's offerings as well. Take Netflix, for example. Its streaming business, which is in direct competition with Amazon Prime's streaming service, runs on AWS.

DISRUPTIVE IMPACT

A concentrated market for an invaluable service creates high risk. It can take several years for a large company to integrate its data into the cloud, making selection a high-stakes choice and the cost of switching prohibitive. The big questions companies must answer first are whether to take a public or private cloud approach, for what parts of the network, and when, taking into account how much value is being created for each party. Companies should also take into consideration the automation and orchestration of applications across multi-cloud, multi-stack, and multi-vendor environments. Embracing a cloud-native approach and its principles of microservices architecture, openness, and DevOps can be more practical, with a clear ownership of data and defined end-to-end service-level agreements that determine who will be responsible for what, and how issues will be resolved.

EMERGING PLAYERS

- Jason Zander, head, Microsoft's Strategic Missions and Technologies team
- Awaiz Khan, Amazon Web Services
- Girish Bablani, Microsoft Azure Core Team
- Corey Sanders, Microsoft's Cloud for Industry and Global Expansion team
- Rob Enslin, Google Cloud
- Kirsten Kliphouse, Google Cloud
- U.S. Federal Trade Commission
- U.S. Federal Communications Commission
- Open RAN initiatives

3RD YEAR ON THE LIST

Interoperability Initiatives

KEY INSIGHT

Tech platforms connecting the cloud, our smart homes, and our everyday digital activities aren't interoperable. Big tech giants use different operating systems for their various devices and ecosystems, which some regulators argue is anticompetitive.



The Connectivity Standards Alliance developed a new protocol called Matter, which will help devices connect to each other.

EXAMPLES

As the number of connected devices grows, there is a growing chorus of support for smart home devices that can seamlessly integrate with other systems while still promising security and uptime. The Connectivity Standards Alliance, formerly the Zigbee Alliance, developed a new protocol called Matter, which acts as an interface between devices. Matter-certified devices—such as those from Samsung, Qualcomm, NXP, and Universal Electronics—would make it easier for devices to talk to each other. In May 2021, Google announced that Android and Nest would run the protocol to connect Matter-certified devices, and Amazon made a similar announcement in early 2022. Comcast launched its new Matter-compatible xFi Advanced Gateway Router at this year's Consumer Electronics Show.

DISRUPTIVE IMPACT

Incentivizing companies to make their protocols and hardware interoperable could help curtail some of the antitrust probes the big tech companies will face this year. The Augmenting Compatibility and Competition by Enabling Services Switching (ACCESS) Act, announced in 2021, would require tech companies to maintain API-like interfaces so that users could port their information over to different platforms if they wanted and smaller companies could more easily make use of our data (with our permission, of course). Interoperability and data portability could eventually lead to new business opportunities and a bigger device ecosystem, if the tech giants are willing to cooperate.

EMERGING PLAYERS

- National Institute of Standards and Technology
- Connectivity Standards Alliance
- Electronic Frontier Foundation
- U.S. Sen. Mark Warner (D-Va.)
- U.S. Sen. Richard Blumenthal (D-Conn.)
- U.S. Sen. Josh Hawley (R-Mo.)

2ND YEAR ON THE LIST

Corporate Denial-of-Service (CDoS)



Former President Donald Trump was deplatformed after the Jan. 6, 2021, attack on the U.S. Capitol.

Image credit: Evan El-Amin/Shutterstock.com.

KEY INSIGHT

When a company denies one or more users, businesses, or governments the ability to access its platform or services, this is an example of a CDoS, a corporate denial-of-service. It's also known as “deplatforming.”

EXAMPLES

After the Jan. 6, 2021, attack on the U.S. Capitol, Facebook denied former President Trump the right to post from his account, and Snapchat instituted a similar, permanent ban. YouTube, Instagram, Twitch, and Shopify suspended Trump, while Twitter banned Trump's account indefinitely and shuttered 70,000 accounts associated with QAnon. Amazon Web Services removed extreme right-wing platform Parler from the cloud, disabling its content and services. Reddit banned r/The_Donald and several pro-Trump pages that intentionally spread misinformation. Web-hosting company Liquid Web removed Oathkeepers.org, the site of the far-right militia group. But deplatforming isn't limited to politics. Uber, Yelp, Airbnb, and many other platforms routinely pull content and ban users, for a wide variety of reasons, from the innocuous (posting what are obviously fake reviews) to the harmful (posts that advocate violence, advance racism, or target religious groups).

DISRUPTIVE IMPACT

In May 2021, Florida passed a social media deplatforming law, making it illegal for companies like Facebook (now Meta) and Twitter to ban users based on their political viewpoints, and a few months later Texas passed similar legislation. CDoSing is a complex issue in the U.S., where free speech laws are strictly enforced but where years of conspiracy theories and misinformation have divided the country on numerous issues, from politics to racial justice to the COVID-19 vaccine.

EMERGING PLAYERS

- First Amendment Center
- Electronic Frontier Foundation
- Benjamin Lee, general counsel, Reddit
- Jennifer Newstead, chief legal officer, Meta
- Vijaya Gadde, chief legal officer, Twitter
- David Zapolsky, associate general counsel, Amazon
- U.S. Sen. Mark Warner (D-Va.)
- U.S. Sen. Richard Blumenthal (D-Conn.)
- U.S. Sen. Josh Hawley (R-Mo.)



Global Tech Policy

3RD YEAR ON THE LIST

Corporate Foreign Policy



Casper Klynge was appointed as Denmark's tech ambassador in 2017.

KEY INSIGHT

Large companies have always lobbied to influence policy and regulation. But as the tech giants amass power and wealth, they're making key decisions that impact diplomacy and geopolitics.

EXAMPLES

In 2017, Denmark appointed Casper Klynge, a long-serving diplomat, to become its tech ambassador. It wasn't a gimmick, but rather a strategic play: The world's largest technology companies have amassed enough power to influence global politics. Last year, a dozen more countries created similar positions, with the aim of mediating disagreements between enormous tech companies and governments, collaborating on shared interests, and developing public-private alliances. Meanwhile, big tech companies are standing up departments dedicated to geopolitics. Microsoft President Brad Smith regularly meets with heads of state and foreign ministers about Russia's hacking efforts, and he developed an international treaty, called the Digital Geneva Convention, to protect citizens against state-sponsored cyberattacks.

DISRUPTIVE IMPACT

Meta, Google, Amazon, Salesforce, and many other tech companies are now building their own teams centered on geopolitics and digital diplomacy. It's one thing for a big company to lobby local lawmakers. Some are now wondering what the longer-term implications might be if corporations actively influence geoeconomics. What if a company's priorities differ from the national priorities of its government at home?

EMERGING PLAYERS

- USC Center on Public Diplomacy
- Kate O'Sullivan, general manager, Microsoft Digital Diplomacy Group
- Meta for Government, Politics, and Advocacy
- Google's business strategy division
- Amazon's public policy team
- Office of Science and Technology Policy

3RD YEAR ON THE LIST

Techno-Nationalism



TikTok's parent company, ByteDance, has strong ties to the Chinese government.

KEY INSIGHT

Technology shapes the ways the countries relate to one another, and it influences the global balance of power. A rising techno-nationalism links a nation's technology capabilities to its economic prosperity, national security, and social stability.

EXAMPLES

A great decoupling is underway, as the U.S. and Chinese tech sectors are cleaved apart by national governments. What began as a rift in the semiconductor, cloud, 5G, artificial intelligence, and biotech industries has bled into other sectors, deepening existing business and economic divides. In the past year, the COVID-19 pandemic only further magnified the ideological differences in political freedoms and human rights, wealth distribution, and the role of government in everyday life.

DISRUPTIVE IMPACT

China's Foreign Investment Law imposes strict rules for vetting foreign investments on national security concerns. Widely seen as retaliation for the former Trump administration's aggressive blacklisting of Chinese companies, the law's intent resembles that of the Committee on Foreign Investment in the United States, which wielded great power and cut Chinese investment from U.S. businesses. Companies must decide whether to remove supply chains from China and how to safeguard company and consumer data if it is housed on Chinese servers. Brands must weigh the marketing value of a viral TikTok video with the risk that accompanies the platform's strong Chinese Communist Party ties. Meanwhile, WeChat and Huawei increase China's influence around the world. As the globe's two largest economies drift apart, companies must navigate business interests and relationships with lawmakers.

EMERGING PLAYERS

- U.S. Department of State
- Committee on Foreign Investment in the United States
- China's Ministry of Commerce
- China's National Development and Reform Commission

6TH YEAR ON THE LIST

Splinternets



: The government of Myanmar restricts what its citizens can see online.

Image credit: R. Bociaga/Shutterstock.com.

KEY INSIGHT

The founding promise of the digital world was broad connectivity where information could flow freely. Governments are taking steps to filter (or completely block) access to the internet, while companies are increasingly instituting subscription models—making wealth a prerequisite for access to reliable information. The world wide web is now splintered into fragments.

EXAMPLES

In 2021, Myanmar's military shut down the internet as thousands of citizens tried to organize a rally against the coup that had taken over the government. Even virtual private networks (VPNs) couldn't bypass the blackout. India has repeatedly shut down phone and internet services to protesters. However, nation-scale internet censorship is most closely associated with China's Great Firewall. At times of political unrest, as during widespread riots in Xinjiang in 2009, China has completely shut down access to the internet. China's leadership believes its model contributes to stability—and is open to exporting that approach to the rest of the world. Splinternets aren't just the product of blocking free access to the internet; sometimes it's enough to just increase the barriers to finding reliable information. That can be a technical roadblock—as in a censorship regime that doesn't remove websites but knows the average user won't have the knowledge or time to connect through a VPN—or a financial one.

DISRUPTIVE IMPACT

The next iteration of the web, which some refer to as web 3.0, could make it difficult for governments to regulate internet access. Also known as the decentralized web, this third version of the internet would introduce new block-chain-based protocols that would allow people to control their own data using a single personalized account. Without a broker in the middle, people could more easily access the same content regardless of where in the world they are—and without the need for an intermediary.

EMERGING PLAYERS

- MIT Digital Currency Initiative
- Syracuse University School of Information Studies
- Sir Tim Berners-Lee's Solid initiative
- Freedom House
- Amnesty International
- Access Now

4TH YEAR ON THE LIST

Multilateral Science and Technology Acts



Several countries are proposing multilateral initiatives to collaborate on the future of science and technology.

KEY INSIGHT

Throughout history, multilateral efforts have resulted in nations working together to promote shared purposes. Proposals to create multilateral initiatives on artificial intelligence, genomic editing, and blockchain are currently being discussed.

EXAMPLES

The U.S. has used its War Production Board to encourage intellectual property (IP) sharing and maximize the production of lifesaving vaccines, medicines, and equipment. During the height of COVID-19, pharmaceutical companies were not compelled to give away their vaccine IP—and that made it difficult for more companies to quickly produce vaccine doses for lower-income nations. This has led to charges of “vaccine apartheid” and growing tensions between emerging economies, the U.S., and E.U. There is precedent for crisis-era agreements between sovereign nations, which previously resulted in the formation of the Geneva Conventions, League of Nations, International Monetary Fund, United Nations, and World Health Organization.

DISRUPTIVE IMPACT

COVID has been a stress test of current cooperative relationships worldwide. Science and technology advancements are leading to new alliances being solidified today that will have downstream effects on other key areas of science and technology—synthetic biology, artificial intelligence, geoengineering, autonomous vehicles, and commercial space travel—for years to come.

EMERGING PLAYERS

- International Union of Biological Sciences
- United Nations
- World Health Organization

2ND YEAR ON THE LIST

Vaccine Diplomacy



China's Sinopharm is a major global distributor of COVID-19 vaccines.

KEY INSIGHT

Effective COVID-19 vaccines exist, but capacity is still meeting only a fraction of the global demand. Tests remain in short supply. Some countries are hoarding resources, while others are using vaccines as a soft power strategy.

EXAMPLES

In 2020, wealthy nations preordered vaccine doses from companies within their preferred trading blocs, and with production unable to keep up with demand, that left dozens of developing economies without a means to protect their citizens. By the middle of January 2021, only 25 doses of the vaccine had been administered in emerging markets. (Believe it or not, that isn't a typo.) In wealthy nations, 39 million had been administered. Those 25 doses were Russia's Sputnik vaccine, and they were given to people in Guinea. By 2021, China was the world's top exporter of COVID vaccines, and doses went to countries that weren't successful in procuring them from the U.S. and Europe. Now, China is using its newfound leverage to push its enormous portfolio of home-grown pharmaceuticals.

DISRUPTIVE IMPACT

COVID has offered China an opportunity to exert its influence through the distribution of vaccines and medical aids. But help frequently comes with strings attached. For example, Chinese embassies often demand public displays of gratitude. In 2021 Serbia launched a national campaign to shower praise on Chinese President Xi Jinping—some politicians insisted on building a statue in his honor. China isn't necessarily seeking reciprocity but is instead building relationships and new alliances over a long period of time—which could ultimately pose threats to the U.S. and Europe.

EMERGING PLAYERS

- World Health Organization
- Sinopharm
- Xiamen Innovax Biotech Co.
- Walvax Biotechnology Co.
- China Power Project, Center for Strategic and International Studies

1ST YEAR ON THE LIST

Space Diplomacy



China will launch its Tiangong space station in 2022. Image credit: China National Space Administration.

KEY INSIGHT

As we enter a new era of space exploration, geopolitical alliances are being formed to propel commercial development—and to develop new military capabilities.

EXAMPLES

On Nov. 15, 2021, the Russian military conducted a direct-ascent anti-satellite test that blew up a Kosmos-1408 satellite, sending at least 1,500 pieces of debris into space. The show of force was a major escalation of Russian space military ops—and debuted a new form of off-planet technology never publicly demonstrated before. Within minutes, astrophysicists warned that debris could potentially collide with spacecraft for many years to come and lead to dangerous outcomes. That ring of debris now lurks directly in the middle of a critical 120 mile space—above it is the International Space Station, and below it is commercial satellite space, where the SpaceX Starlink fleet orbits. The U.N. General Assembly adopted a resolution, drafted by the U.K. and signed by 21 countries, agreeing that participating member states should share information about their space security policies and any activities they deem irresponsible or existentially threatening—but it failed to prevent the anti-satellite test.

DISRUPTIVE IMPACT

China is working to make its space research, equipment, and artifacts available to foreign researchers, as part of a broader diplomatic effort. China now operates the world's largest radio telescope, and it has acquired fresh moon samples—the first in nearly 45 years. Foreign researchers are being actively courted—outside of the U.S. That's because since 2011, Congress has banned NASA from using its funding for any joint research activities with China or Chinese-owned companies. Would it ban NASA from working with researchers who currently or previously contributed to Chinese research? If so, that could become a problem, given China's aggressive outreach efforts.

EMERGING PLAYERS

- China National Space Administration
- Roscosmos State Corporation for Space Activities
- European Space Agency
- NASA
- U.S. Space Force

1ST YEAR ON THE LIST

Geoengineering Policy



Harvard's Stratospheric Controlled Perturbation Experiment (SCoPEX for short) hopes to release a balloon this year to gather initial data.

Image credit: NASA.

KEY INSIGHT

New technologies promise to stabilize climate change, but they could damage international relations.

EXAMPLES

Geoengineering is broadly defined as the “large-scale manipulation of an environmental process that impacts the Earth’s climate in an attempt to counteract global warming.”¹ Solar geoengineering is a technique that uses technology to reflect solar radiation back into space, and different approaches are being considered. One is to spray aerosol particles of calcium carbonate (the stuff found in antacid tablets), which can act like nano-mirrors and deflect the sun’s harmful rays from hitting Earth. The Stratospheric Controlled Perturbation Experiment (SCoPEX for short) hopes to release a balloon this year to gather initial data. The experiment would only release 1 kilogram of calcium carbonate, which won’t exactly move the mercury down our thermometers—but would allow scientists to determine whether the technique might work on a bigger scale. But this research is controversial. A trial planned for early 2021 was abandoned due to protests from environmental groups.

DISRUPTIVE IMPACT

Many people don’t believe that scientists should attempt to manipulate our climate, and that reducing CO2 emissions is safer. This year, new solar geoengineering trials will take place. The challenge is that Earth is warming at an alarming rate, and so far the focus has been on restrictions and punitive measures. Geoengineering efforts—which also include dropping iron deposits into the ocean, and growing different types of plant species—could give us optionality. But we need a way to align on policy to govern the atmosphere first. The SCoPEX experiment’s biggest success might not be in cooling the atmosphere but rather catalyzing global geoengineering policy.

EMERGING PLAYERS

- Stratospheric Controlled Perturbation Experiment
- U.K. House of Commons Select Committee on Science and Technology
- U.N. Framework Convention on Climate Change
- U.N. Convention on the Law of the Sea
- Johns Hopkins Applied Physics Laboratory
- World Bank

1ST YEAR ON THE LIST

Neurorights Campaigns



Chilean Sen. Guido Giradi is leading an effort to regulate the use of brain data harvested from neurotechnology.

Image credit: Wikimedia Commons.

KEY INSIGHT

As neurotech moves from labs into trials, some countries are banning the collection and sale of brain data.

EXAMPLES

Neurotechnology includes brain-machine interfaces and implants capable of reading and translating electrical signals. Promising devices include prosthetic limbs, which can be stimulated with electrical pulses and turned into movement commands. Less practically: Elon Musk has promised that his neurotech startup, Neuralink, is working on brain implants that could enhance cognition. This has sparked some governments to pre-regulate neurotech. Spain launched a Digital Rights Charter in 2021, and it includes a provision on neurorights and protecting citizen data. The U.N. published an agenda last fall arguing in favor of reviewing neurotech in the context of human rights.

DISRUPTIVE IMPACT

The most aggressive neurotech regulations are now in Chile, where a new constitutional amendment prohibits mind control, mind reading, or any other technology that might interfere with how people think. This approach, which effectively categorizes all neurotech as medical devices and strictly limits their use to very narrow cases, could stifle innovation as the technology is still being developed. But a growing number of activists are calling for a thorough public debate on the rights to mental privacy—and transparency into how the data extracted from users' brains could be used for commercial purposes.

EMERGING PLAYERS

- NeuroRights Foundation
- U.S. Brain Research Through Advancing Innovative Neurotechnologies Initiative
- Senator Guido Girardi, lead sponsor of China's neurorights bill
- Neuralink



China Focus



We Chinese know only too well what it takes to achieve prosperity so we applaud the achievements of others and we wish them a better future. We are not jealous of others' success and we will not complain about the others who have benefited. We will welcome them aboard the express train of Chinese development.

— Xi Jinping, President of the People's Republic of China



1ST YEAR ON THE LIST

China's Tech Crackdown



KEY INSIGHT

The Chinese government is cracking down on its largest tech companies, citing anticompetitive behavior and regulatory infractions. The reason likely has to do with an interest in focusing tech development to align with national priorities.

China is cracking down on its biggest tech companies for anticompetitive behavior, among other things.

Image credit: Koshiro K/Shutterstock.com.

EXAMPLES

Last year, Beijing ordered Didi Chuxing—the world's largest ride-sharing company—to submit to a probe for alleged data privacy and national security breaches. Government officials had launched the probe just days after Didi's enormous \$4.4 billion IPO on the New York Stock Exchange. But more pressure mounted, and fast: By July, the Cyber Administration of China had added 25 apps operated by Didi to its banned products list. Before Didi attracted the ire of Beijing, Alibaba was fined a staggering \$2.5 billion for antitrust violations, and the government forbade the IPO of its financial services arm, Ant Group.

DISRUPTIVE IMPACT

Increasingly, Beijing is interested in its mega-successful big tech companies—Baidu, Alibaba, and Tencent, among others—working to share data with the state and to perform research to support the vision of the Chinese Communist Party. Rather than making popular video games, Beijing aims to direct the might of its tech companies toward programs of national strategic importance. China's tech crackdown could cool private investment in Chinese companies, which could result in a chilling effect on innovation and economic growth but free up capital for emerging markets.

EMERGING PLAYERS

- Cyber Administration of China
- China's State Administration for Market Regulation
- Center for Strategic and International Studies

How To Stream Game of Thrones Re-Finale • Near-future pessimistic scenario



Posted by u/clarinone9322 15 hours ago



56.4k

**What is the best VPN to stream the “fixed” final season of Game of Thrones being aired on Tencent in China?**

Like everyone else in America, I want to watch the “fixed” Chinese episodes of the final season of GoT. I've heard from friends in the Philippines that the deepfake tech they used to reshoot scenes is amazing.

SPOILERS AHEAD! They improved the visual quality of “The Long Night” so you can actually see what's going on in the battle involving the Night King without having to mess around with the brightness settings on your TV. In the new version, rather than Jaime randomly teleporting (?!?) to be with Cersei in the middle of his redemption arc, he joins Jon and the fight at King's Landing instead. Plus Daenerys no longer sets fire to LITERALLY EVERYTHING for no reason. Instead she accepts the surrender of Lannister forces. And I heard they added new content in the last season so it no longer feels so rushed and confusing.

I can't get a subscription to Tencent, so does anyone have a suggestion on how to stream the new episodes?

2878 comments Share Save Hide Report



Chxxliuse98 • 8 hours ago

I'm having the same problem. China is blocking the US from using Tencent. But you can watch clips on TikTok.

87 Reply Share Report Save Follow



mils-3orusw • 2 hours ago

I use XinVPN and it is fast for streaming.

33 Reply Share Report Save Follow



Dany_Boi_DD • 1 hours ago

Thanks! I think I'm still being blocked. Is it a Chinese VPN?

6 Reply Share Report Save Follow



LimesALot12 • 1 hours ago

Every VPN seems to be having problems right now. I had luck using servers in Italy and Thailand.

14 Reply Share Report Save Follow



r/technology

Subreddit dedicated to the news and discussions about the creation and use of technology and its surrounding issues.

11.4m
Members

9.1k
Online

Created Jan 25, 2008

Join

r/technology Rules

1. Submissions must be about technology
2. No images, audio, or video
3. Titles must be taken directly from the article
4. No technical support or help questions
5. No petitions, surveys, or crowdfunding
6. No meta posts

3RD YEAR ON THE LIST

China's Quest for Cyber Sovereignty



Last year, after global tennis sensation Peng Shuai spoke publicly about being sexually assaulted by a top CCP official, her social media accounts were frozen and all mentions of her story were scrubbed from Chinese cyberspace.

Image credit: Lev Radin/Shutterstock.com.

KEY INSIGHT

Cyber sovereignty refers to a government exerting control over how the internet is run, who gets access to it, and what can be done with all of the data generated.

EXAMPLES

The Chinese Communist Party argues that China is an enormous country in the midst of the fastest economic transition in modern history, and its unique controls promote social and economic stability. As a result, Beijing says that it has developed unique protocols required of a country in transition. In 2021, when Chinese tennis star Peng Shuai went on social media to accuse a top CCP official of sexual assault, her account was closed, and any subsequent mention of her name or story was immediately scrubbed from Chinese cyberspace. She then dropped out of global view entirely, only to eventually resurface making an apology for what she'd written. Meanwhile, provocative crackdowns on Hong Kong by the CCP resulted in an expansion of China's Great Firewall, a tightly controlled version of the internet that blocks entertainment, journalism, and commentary that challenge the government's ideas.

DISRUPTIVE IMPACT

Beijing intends to wean China off foreign-made computers and operating systems, replacing familiar brands (Microsoft, Dell, Apple) with Chinese products. The CCP argues that China's digital and information systems can serve as a new model for other countries around the world and that other regimes can follow suit. China's Belt and Road Initiative, which has successfully expanded trade throughout emerging economies, has boosted the country's digital initiatives. Within a decade, the digital world could be split in two: a free system in the West and a closed system led by China.

EMERGING PLAYERS

- Ren Zhengfei, Huawei founder
- Lei Jun, Xiaomi founder
- Pony Ma, Tencent founder
- Cyber Administration of China
- China's State Administration for Market Regulation
- Center for Strategic and International Studies



- 00
- 01
- 02
- 03
- 04
- 05
- 06
- 07
- 08
- 09
- 10
- 11
- 12
- 13

Security

Security

A very brief list of 2021 attacks and breaches.

January

Supply chain attack

Hafnium, a Chinese state-backed hacking group, exploited vulnerabilities in Microsoft Exchange Server software. The exploit targeted small businesses and local governments in the U.S. Globally, Norway's Parliament and the European Banking Authority were impacted.

Data breach

Chinese social media management company Socialarks leaked personally identifiable information of 214 million users. The breach was due to an unsecured database and included Facebook, Instagram, and LinkedIn profile data.

Data breach

ShinyHunters attacked men's clothing retailer Bonobos, scoring personally identifiable information for more than 7 million users. Partial credit card numbers, home addresses, phone numbers, and other account information were uploaded to a forum for hackers—for free.

Data breach

The largest data breach in Brazilian history included names, tax IDs, facial images, salaries, and more. The data was offered for free to hackers on a darknet forum.

February

Ransomware

A cybercriminal group known as Cuba breached AFTS, a payment processor, and stole financial information.

March

Cyber espionage

Tether, a cryptocurrency hosted on the Ethereum blockchain with tokens issued by Tether Ltd., was infiltrated by hackers who promised to leak documents that they claimed would “harm the Bitcoin ecosystem.” Tether refused to pay and announced that the documents had been forged.

Ransomware

U.S. insurance giant CNA Financial agreed to pay \$40 million, which at the time was the highest amount paid to retrieve stolen data.

April

Data breach:

Facebook experienced a brutal attack involving the data of 550 million users. Facebook IDs, birth dates, gender, location, and other data were published online.

May

Ransomware

Colonial Pipeline, which operates a 5,500-mile gasoline, diesel, and natural gas pipeline carrying much of the East Coast's fuel, was hit with a ransom attack. With shortages and long lines at gas stations, the U.S. Department of Transportation created an emergency order allowing fuel to be distributed

by truck. The FBI named the Russian-linked cybergang DarkSide as the attacker. Colonial Pipeline paid a 75 bitcoin ransom (roughly \$4 million) to regain access to its digital systems. The U.S. State Department later offered a \$10 million bounty for information leading to arrests.

Vulnerability

Due to the misconfiguration of cloud services, more than 100 million Android users' data was potentially exposed via more than 20 apps that were not protecting real-time databases.

June

Ransomware

JBA SA, the world's largest meat processing company, was hit with a massive ransomware attack. It impacted facilities in the U.S., Canada, and Australia, and led to plant shutdowns, caused livestock to be returned to farms, and temporarily resulted in global meat shortages.

Data breach

Audi and Volkswagen disclosed a breach impacting 3.3 million customers, primarily located in the U.S.

July

Supply chain attack

Russian-linked cybergang REvil exploited a flaw in IT management software company Kaseya, which allowed hackers to inject 1,500 organizations with malware.

Commercial hacking

Spyware developer NSO Group was found to have been creating and selling tools to infect iOS targets via flaws in Apple's iMessage communications platform. A group of researchers published forensic evidence revealing that several governments—Saudi Arabia, the United Arab Emirates, Hungary, India, Morocco—could be NSO customers.

Security

A very brief list of 2021 attacks and breaches.

Cyberattack

UC San Diego Health reported that employee email accounts had been infiltrated, giving hackers potential access to the academic health system's medical records, claims information, prescriptions, treatments, and Social Security numbers.

August

Data breach

T-Mobile reported a breach that involved IMEI and IMSI numbers, names, addresses, driver's license numbers, and Social Security numbers for approximately 50 million customers.

Smart contract hack

Poly Network, a blockchain organization, announced a smart contract hack that was used in a \$600 million cryptocurrency heist.

Smart contract hack

Liquid, the Japanese cryptocurrency exchange, had \$97 million in crypto stolen.

September

Cyberattack

Cream Finance, a decentralized finance organization, blamed a vulnerability for a \$34 million loss.

Bio-cyberattack

The public hospital system in Paris reported that private health data, including COVID-19 test results, was stolen.

October

Data breach

Amazon-owned Twitch announced that a massive 128-gigabyte cache of data—including proprietary software development kits and the livestreaming service's complete source code—had been stolen. Individual streamers' payout data was included in the files.

Crypto attack

Coinbase announced that hackers tried to gain access to its user accounts. Cryptocurrency was successfully transferred out of some user accounts without their knowledge.

November

Data breach

The Robinhood trading app disclosed a breach involving 5 million users.

December

Crypto attack

\$150 million in cryptocurrency was stolen from BitMart due to a security breach.

Zero-day

In perhaps the most stunning exploits of 2021, a zero-day vulnerability was discovered in a relatively small but popular Java library used for tracking software events. This prompted the White House to host an emergency tech summit to

discuss open-source security, given that so many companies rely on open-source tools and software.

Sources

Bluefin, Krebs on Security, Security Magazine, ZDNet, Kaspersky



AI naturally gravitates toward monopolies... once a company has jumped out to an early lead, this kind of ongoing repeating cycle can turn that lead into an insurmountable barrier to entry for other firms.

— Brad Smith, President of Microsoft, writing in *Tools and Weapons: The Promise and the Peril of the Digital Age*



Bio-Cyberattacks



Ransomware attacks will continue to challenge COVID management efforts in 2022.

■ COVID-Related Hacking

With the global pandemic forcing fast coordination by government agencies, researchers, and pharmaceutical companies, vaccine and patient data became a new target for cyberattacks. In August 2021, the Indiana Department of Health confirmed that data from its statewide COVID-19 contact tracing database had been accessed by hackers, while in December 2021, the Maryland Health Department was unable to publish data on new coronavirus case rates for nine days due to a network security incident. Hackers are targeting patient data, COVID research, genetic code, and vaccine intellectual property. Given the continued spread of SARS-CoV-2 variants, hackers eye a lucrative community to exploit.

■ Biometric Malware

Biometric data isn't stored as securely as it should be, opening the door to theft

and manipulation. There have been plenty of attacks in recent years, including the emergence of a tool that can scrape photos from social media and use them to launch sophisticated phishing attacks. Malware called CamuBot targeted Brazilian bank customers, bypassing biometric hardware protections for device takeover. Using biometrics to keep people safe while they travel or during the pandemic could also put them in greater danger.

■ DNA Database Hacks

As more consumers send their saliva away for genetic testing, the need for secure DNA databases has never been as important. In July 2020, hackers were able to access GEDmatch, a DNA database, resulting in the genetic profiles of 1 million users being searched by law enforcement. A few weeks later, hackers used the emails retrieved from GEDmatch to launch another attack,

this time on genetic testing company MyHeritage. Sensitive DNA information could be used for a number of purposes, from blackmail to government espionage.

■ Cyber Homicide

The first known death resulting from a cyberattack happened in 2020. Intending to extort money from Düsseldorf University, attackers locked its local computer network—which included the computers at the university hospital. At that moment, a woman who needed immediate surgery couldn't be seen, resulting in her being transferred to another hospital. Time ran out, and she died. Since then, there have been several more cases of cyber homicide, and according to cybersecurity company Censinet, a quarter of health care organizations that experienced a ransomware attack in the past two years reported increases in patient death

rates. Hospitals rely on computerized machinery, logistics, and transportation systems. Taking them offline for a ransomware attack, even for a few hours, causes real-world harm. Security experts are increasingly concerned about accidental incidents, as well as those caused intentionally. Bad actors could take down a hospital's entire computer system just to target one patient.

Critical Attacks



The SolarWinds attack highlighted the vulnerability of cybersecurity's supply chain.

■ Supply Chain Attacks

Cybersecurity has its own supply chain, which includes IT services, vendors, software, networks, and data. The 2020 SolarWinds attack is an example of a supply chain attack, because it compromised the systems management tools used by IT professionals. The impacts are still cascading throughout the ecosystem. SolarWinds was a prime target—breaching the supply chain meant potentially gaining access to hundreds of thousands of companies and government agencies. In a supply chain attack, hackers infiltrate your systems through an outside partner that has access to your data. Nearly every company must use outside hardware and software—it would be impossible to build everything a modern company needs from scratch—and reliance on outsiders requires tight security. Security is only as good as its weakest link, and supply chain attacks are growing in both frequency and sophistication.

■ Zero-Day Exploits Rising

A zero-day vulnerability is a flaw—a problem within a hardware or software system that developers didn't discover during the testing process. That vulnerability can be exploited by malware to cause all sorts of problems. Zero-days are dangerous, prized tools, and discovering them is a favorite activity of malicious hackers. Once the flaw is revealed, programmers have zero days to do anything about it. Last year set a new record for zero-day attacks—66 known zero-days were found in use, which is double what was discovered a year earlier. The zero-day marketplace, where tools are bought and sold, is lucrative and growing. Tools to exploit vulnerabilities will be in greater demand through the near future.

■ Zero-Knowledge Proofs Go Commercial

With all the hacking scandals that have plagued us in the past several years, we will see a transition to something called zero-knowledge proofs, which allow one party to verify data without conveying any additional information. For example, researchers at Microsoft and a handful of universities are collaborating on Picnic, which is the code name for a post-quantum digital signature algorithm, and it uses a zero-proof system. Picnic uses this concept together with symmetric cryptography, hash functions, and block ciphers, to create a novel signature scheme. It's a mind-bending approach to security, allowing you to verify your identity without actually revealing who you are. In essence, this eliminates the need for a company to store private identity data during the verification process. Zero-knowledge proofs aren't new, but deploying them

to protect our digital identities is an emerging application, especially in the wake of increased telemedicine and remote work. JPMorgan Chase is using zero-knowledge proofs for its enterprise blockchain system, while Ethereum is using zero-knowledge for authentication.

Cyber Policy



Messy code allowed hackers to infiltrate platforms in 2021.

■ Regulating Messy Code

For the past few years, some social media users left big platforms for nascent startups that were established quickly and with little technical oversight. Anger toward Twitter and Facebook (now Meta) catalyzed the growth of newer entrants, such as Signal and Telegram, which promised encrypted private messaging, and Clubhouse, which offered private chat rooms that could be controlled by hosts. Meta-owned WhatsApp confused its global user base because of a sloppy announcement about data sharing and privacy: It notified users they would get new options to message businesses but had to opt in or their service would be cut off. (Practically speaking, very little changed, but in the haze of confusion, users left in droves and joined Signal and Telegram.) Sloppy code and a mess of security failures allowed a hacker to infiltrate Parler, a Twitter clone launched by former President Trump supporters. Parler's

public API didn't require authentication, the site didn't actually remove deleted posts, and, inconceivably, each post used a sequential numerical ID, making it simple to scrape data. Geolocations weren't scrubbed, metadata was preserved ... we could go on. The result: 80 terabytes of posts, including 1 million videos, were made available online. Lawmakers are investigating whether they can force companies to clean up their code—which could include regulating the testing and maintenance of open source code repositories.

■ Global Cybersecurity Pacts

In late 2018, more than 50 countries signed an international agreement on cybersecurity principles. Along with those countries were more than 200 companies (Microsoft, Google, and Facebook among them) that committed to end malicious cyber activities in peacetime. While the agreement was

nonbinding, it was an attempt to develop norms and standards for the ways in which countries behave in cyberspace. Noticeably absent from the list of signers: Russia, China, North Korea, Israel, and the United States. The Biden administration signaled its focus on cybersecurity as a top national security policy, and last year the State Department opened the Bureau of Cyberspace and Digital Policy.

■ Government Requests for Backdoor Access

While they sound malicious, backdoors aren't necessarily bad. Often, developers intentionally install them into firmware so that manufacturers can safely upgrade our devices and operating systems. The challenge is that backdoors can also be used surreptitiously to harness everything from our webcams to our personal data. In 2020, Republican lawmakers introduced the Lawful

Cyber Policy



U.S. Secretary of State Antony Blinken established the Bureau of Cyberspace and Digital Policy.

Image credit: Drop of Light/Shutterstock.com.

Access to Encrypted Data Act, which would result in weaker encryption in communication services so that law enforcement officials could gain access to devices with a warrant. Government officials worldwide have been advocating for a set of “golden keys,” to allow law enforcement to break through the security using backdoors. But even without public agreement, some agencies may find their way into our machines. In 2013, the National Security Agency made a deal with security company RSA to include a flawed algorithm, effectively giving the NSA a backdoor into various systems. The challenge is that the simple act of creating a backdoor would leave ordinary people vulnerable to everyday attacks by a wide swath of actors, both benevolent and malicious. However, given the rise of zero-day exploits, we should question whether backdoors are the best way forward.

■ Remote Kill Switches

As our technology becomes more immersive, we’ll have increased needs for remote kill switches. Found on smartphones and connected devices, these will soon come in handy for the enterprise and government agencies. Uber developed its own software program called Ripley, which could be activated by staff in San Francisco, should any of its overseas offices be raided by police. It also deployed uLocker, a remote kill switch that could lock all company devices, including laptops and phones. On the consumer side, both Apple and Android devices now allow users to remotely wipe all information from their phones and tablets using a web interface. That benefit would come with a cost, however. Kill switches would mean that nobody could gain access to what’s inside a lost or stolen phone—not even law enforcement.



Cyberweapons are going to be used in a way we haven't used other weapons. It gives us options we didn't have before.

— James Lewis, a cyber expert,
Center for Strategic and International
Studies.

Cyberwarfare



Every year, cybercriminals target critical infrastructure.

■ Automated Attacks Using AI

Thanks to advancements in AI, one of the big trends in security is automated hacking—in short, software that’s built to out-hack the human hackers. The Pentagon’s Defense Advanced Research Projects Agency launched a Cyber Grand Challenge project in 2016, with a mission to design computer systems capable of beating hackers at their own game. DARPA wanted to show that smarter automated systems can reduce the response time—and develop fixes in system flaws—to just a few seconds. Spotting and fixing critical vulnerabilities is a task that might take a human hacker several months or even years to complete, and yet the machine that won the Grand Challenge proved its might in just a fraction of that time. The winner became the first nonhuman entity to earn the DEF CON’s Black Badge, which is the hacking community’s equivalent of an Oscar. Very soon, malicious actors will create autonomous systems

capable of automatically learning new environments, exposing vulnerabilities and flaws, and then exploiting them for gain—or whatever the stated objective, which could simply be generalized mayhem.

■ State-sponsored Security Breaches

It’s thought that the 2020 SolarWinds supply chain attack was likely planned and facilitated by an elite Russian government agency, while Russian hackers targeted more than 20 U.S. states’ voter registration databases leading up to the 2018 elections. But there is evidence that the Russian government had a long list of targets that went far beyond American politicians running for office. Russian hackers targeted thousands of people, from defense contractors at Lockheed Martin and Raytheon, to Ukrainian lawmakers, to the pope and his executive team. Russia is home to some of the world’s most gifted and

prolific hackers. Elite digital forces in Russia and China are targeting managed service providers that provide IT infrastructure. And they aren’t necessarily covering their tracks as they did in the past. Outside of state-sponsored cyber initiatives, plenty of talented people may be motivated both by a lack of economic opportunity and weak law enforcement. Over time, this has created a perfect storm: Enormously talented people, weak laws, and poor economic conditions have led to a growing pool of talented hackers.

■ Critical Infrastructure Targets

Every year, cybercriminals target critical infrastructure and facilities, and for years, security experts have warned that hackers could potentially disable dams, power plants, and traffic lights with these attacks. Last year, it was revealed that hackers had remotely accessed the water supply of a city near Tampa Bay, Florida, and had adjusted the amount

Cyberwarfare



Hacker Anonymous declared cyberwar on Russia in February 2022 following that country's attack on Ukraine.

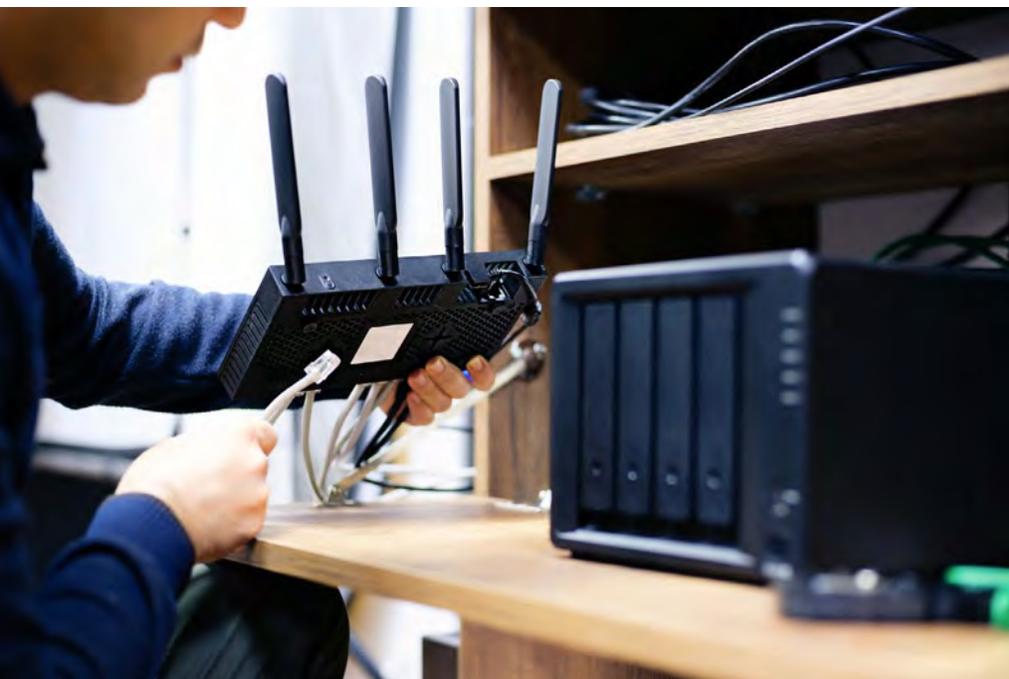
of lye to levels harmful to humans—fortunately the attack was identified and thwarted before the tainted water reached any homes. Another group of hackers hit the jackpot during the SolarWinds supply chain attack, targeting vital facilities in countries around the world. And four years ago, Russia targeted critical infrastructure sectors in the U.S., including the power grid—though it's been trying to gain access to that since at least 2016—and hackers did gain access to one power plant's control system. At the time cybersecurity company Symantec warned that hackers had penetrated the U.S. power grid, targeting staff at nuclear energy facilities with phishing attacks. The U.S. Computer Emergency Readiness Team issued a sternly worded notice but one that lacked an enforcement mechanism, and it's clear that the companies and utilities managing our critical infrastructure haven't yet been jolted into action.

■ Offensive Government Hacking

Rather than simply pursuing cyber deterrence, governments are more actively engaging offensive positions in cyberwarfare. It's been a decade since the U.S. and Israel joined forces to deploy a devastating worm known as Stuxnet, which took down parts of Iran's covert nuclear weapons program. Singapore's Ministry of Defense is hiring white hat hackers and security experts to look for critical vulnerabilities in its government and infrastructure systems. In the U.S., the two agencies responsible for cyberwarfare—the U.S. Cyber Command and National Security Agency—are playing offense, especially as artificial intelligence becomes a focus for the nation's cyber strategy. Eventually, AI could enhance offensive operations and replace human troops, but the agencies face a shortage of gifted hackers willing to join government ranks. That could change with the Biden administration,

which is actively promoting science and technology as it tries to rebuild trust in the government.

Safeguarding the Home of Things



Most consumers do not regularly update their routers, leading to potential security problems.

■ WFH Security

With so many people now working from home and using their own routers, home computers, and internet service providers, hackers are finding it easier to breach company data. Cybercriminals are increasingly targeting inadequate data security protocols. They're also reigniting fraudulent emails, phishing, and spam campaigns related to WFH and COVID-19 as a way to gain entry into intellectual property, corporate data, and customer information.

■ Consumer IoT Vulnerabilities

With the proliferation of smart devices—connected speakers, mirrors, and fitness gadgets—hackers have a well-spring of new targets in 2022. Especially because consumers don't always update firmware, security patches, or even their passwords. Internet of Things security is bad, and this year we are likely to see new threats. Many IoT devices ship

with insecure default settings, which then often remain unchanged after the consumers set them up in their homes. Insecure routers and Wi-Fi configurations are also problematic. Attackers might find a way into a company database or hijack your smart TV for ransom the day before a big televised event (national elections, Eurovision, the Super Bowl) and refuse to unlock it until you've paid a fee. Companies that now have legions of employees working from home should closely monitor internet service providers (ISPs), smart devices, and local network configuration.

■ Sonic Lock Picking

Machine learning is being used to recognize and regenerate sounds, including the sound of someone inserting a key into a lock. The unique sequence of metallic clicks can be deciphered using signal processing software to replicate the precise shape of the key shaft in a

computer rendering program, from which a functional plastic clone key can then be 3D-printed. It's an example of a major vulnerability in legacy security systems that include older safes and traditional locks.

Corporate Security and Espionage



HackerOne hosts white hat bounty programs to uncover vulnerabilities before hackers infiltrate digital systems.

■ Bounty Programs

White hat (read: good hacker) bug bounty programs are becoming popular. In some cases, businesses solicit friendly hackers for paid work through platforms like HackerOne, which is used by the U.S. Department of Defense, WordPress, Coinbase, Shopify, and GitHub. HackerOne and the Defense Digital Service announced a new bug bounty program, in which participants attempt to uncover vulnerabilities in the U.S. Army's digital systems. Verizon Media has paid \$9.4 million and resolved nearly 6,000 bugs.

■ Data Theft Becomes Data Manipulation

Rather than malicious actors simply stealing data, you can expect to see new kinds of attacks involving hackers accessing and then manipulating data for long-term damage. The implications are more concerning than you might realize

at first: If a company's vigilance over its data integrity is cast in doubt, it could quickly lose customers and partners.

■ Low-Cost Malware

Older malware is being remixed and used for new purposes. For example, two older types of malware enabled a remote administration tool to infect Android phones with a keylogger, allowing attackers to monitor the use of websites and apps. For \$29.99, low-level cybercriminals could easily steal usernames and passwords.

■ Cyber Risk Insurance

New forms of insurance, intended to help businesses protect against hackers, will begin to enter the marketplace. Rather than simply covering the theft of basic information, insurers will also offer protection against damage to reputation, the loss of operational capacity, and the costs for system upgrades. As

organizations develop their next fiscal year budgets, they should assess the need for cyber risk insurance.

Internet Traffic



New “smart” DDoS attacks are on the horizon.

■ DDoS Attacks on the Rise

A distributed denial-of-service (DDoS) attack happens when a hacker sends so many requests to a battalion of machines that the entire network goes down. In the past several years, the number of DDoS attacks has spiked—and the attacks are increasing in both reach and duration. DDoS attacks were up 31% last year and were much more sophisticated than previously seen. New “smart” DDoS attacks aren’t just used to disrupt services—they are also used to steal money or to render resources inaccessible. To date, half of the world’s attacks have originated in China. Hackers are using more sophisticated tools, which means that future attacks will be larger in scope and could achieve greater impact.

■ Hijacking Internet Traffic

The protocols underpinning the web were written long before we had connected microwaves and billions of daily users. In 2018, hackers created a massive internet traffic diversion, rerouting data through China, Nigeria, and Russia. It disrupted Google, taking its business tools offline, slowing down search, and making its cloud unreachable. It was an example of Border Gateway Protocol hijacking and, while in this case the error was the result of an outdated Nigerian ISP, the incident points to a vulnerability in our web infrastructure. We saw multiple cases of internet traffic hijacking in 2021, especially as more people worked from home.

Hactivism



Twitch was infiltrated by hactivists because they were angry about how the platform was being used by others.

■ Ransomware-as-a-Service

Last year, ransomware devastated companies and even entire cities. In a ransomware attack, hackers deploy malicious tools to hijack data, effectively locking out systems and devices, until a fee is paid. Since cash and online bank transfers are easy to track, the currency of choice is now bitcoin, which moves through an encrypted system and can't be traced. The emergence of the blockchain and cryptocurrencies have transformed ransomware into a lucrative business. In 2021, Baltimore was one of dozens of cities hit by municipal ransomware attacks. Residents couldn't pay water bills, email their city representatives, or schedule trash pickup, among other things. Cities, financial services, and health care organizations have been targeted with the brunt of ransomware attacks because the data and services they provide are so valuable. Simply backing up your organization's data

won't be enough of a fail-safe going forward. Researchers have already found “doxware” floating around the internet—rather than just holding your data hostage until you pay up, you face the threat that it could all be published to the web, for everyone to see.

■ Decentralized Hactivists

Hackers-turned-activists have had a busy few years, working for causes they believe in. They launched DDoS attacks against governments, corporations, and banks. Hactivist organizations, including Anonymous, WikiLeaks, and DC Leaks, see themselves as enduring forces of change. In 2020, Anonymous organized attacks on multiple law enforcement websites in support of Black Lives Matter protesters, and in October 2021, hackers infiltrated Amazon-owned streaming platform Twitch because they said the site had become a “disgusting cesspool.” Hactivists will use their

skills to help shape local, state, national, and international politics, conversations, and business practices.

■ Proliferation of Darknets

Many people confuse the deep web—hidden parts of the internet that aren't usually indexed by search engines—with darknets, which are niche spaces promising anonymity, often for illegal activities. People go there to sell and buy drugs, guns, ammunition, security exploits (malware, ransomware) and your hacked data (passwords, credit card numbers, and more). Cryptocurrencies have fueled activity in the dark corners of the internet, since they're encrypted and make tracking transactions nearly impossible. You can't just hop on to a darknet the way you Google your high school sweetheart. To access the hidden crime bazaars, you need special software such as the Tor Browser or Freenet, you need to know where

you're headed, and you do need a bit of technical knowledge. It isn't illegal to take a walk through dark marketplaces. But there's also plenty of good activity that takes place in anonymous web portals: whistleblowers hoping to shine a light on wrongdoing, political dissidents looking for asylum, and investigative journalists hunting down leads. As cryptocurrencies gain popularity, we're likely to see more activity in darknets. Activists with legitimate concerns will advocate for new layers of protection, while law enforcement will receive training on how to navigate the dark web. For government and law enforcement, the challenge of training is that unregulated and at times purposely evasive dark websites are insular and ever-changing. Those accessing darknets are typically also the ones building them.

Cybersecurity Terms Every Executive Should Know

Access control

A selective restriction that controls what data users and user groups can access, see, share, and edit.

Adware

Software that automatically generates online ads; it can also include spyware that tracks your browsing habits. It's because of adware that many people are turning to ad blocking software.

Air gap

A system that is physically separated and isolated from all other computers, networks, and the internet.

Anonymous

A collective of hackers, best known for its use of the Guy Fawkes mask and distributed denial-of-service (DDoS) attacks. Anonymous typically uses the hashtag #Ops when announcing a new campaign. Past ops

included a takedown of the Church of Scientology and the Westboro Baptist Church.

Authentication

A verification process that confirms the identity of a user based on specific information.

Backdoor

Developers intentionally install backdoors into firmware so that manufacturers can safely upgrade our devices and operating systems. The challenge is that backdoors can also be used surreptitiously to access everything from our webcams to our personal data.

Black hat

A malicious hacker; someone who hacks for personal gain.

Bot

Bots are automated programs that perform a simple task. Some—simple

chatbots, for example—are completely harmless. Other bots can be programmed to repeatedly guess passwords so that a hacker can break into a website.

Botnet

A botnet is a group of computers that are being controlled by a third party, and are being used for any number of nefarious purposes. For example, malware installed on your computer can run undetected in the background while hackers use your machine as part of a large spamming network.

Breach

The moment a hacker gains access to a device or network via a vulnerability.

Bring Your Own Device (BYOD)

A policy that authorizes employees to use their own devices on the company network or to access company data.

Browser hijacking

This attack changes a user's default homepage and search engine without permission, often in order to gain clicks to websites for ad revenue or to inflate a page's ranking.

Brute force attack

This type of attack is a laborious, methodical process where a hacker uses software to automatically guess every password it can to gain unauthorized entry into a network or computer.

Bug

A flaw or problem in a program that can be harmless or might allow hackers to exploit a system.

Cloud

Data storage or computing services that are accessed using remote servers.

Cookie

A small file sent from your computer's web browser to a server. Cookies help websites recognize you when you return, and they also help third parties track their audience.

Cracking

A basic term that describes breaking into a security system. Anyone "cracking" a system is doing so maliciously.

Crypto

Cryptography (or "crypto") is the art and science of encrypting data—as well as breaking encryption. (The term is also used as shorthand for the cryptocurrency market and its various tokens.)

CxO spoofing

Cybercriminals digitally impersonate a company's executive leadership team to gain access to IP, data, or other sensitive information.

Cybersecurity Terms Every Executive Should Know

Cyberattack

An attempt by a bad actor to gain access to a computer system, device, or network for the purpose of collecting data, monitoring activity, or causing damage.

Dark web

Encrypted networks that are not easily accessible by outsiders. Users are anonymized. Illegal activities are often carried out on the dark web, such as selling company data.

Data leakage

The unauthorized access of information resulting in leaks, theft, or loss.

Denial-of-service attack (DoS)

This is when a hacker sends so many requests to a website or network that the traffic temporarily overwhelms the servers, and the site or network goes down.

Digital certificate

These authenticate and approve the identity of a person, organization, or service.

Distributed denial-of-service attack (DDoS)

This is a DoS using a battalion of machines.

DNS hijacking

This attack changes a computer's settings to ignore a domain name system (DNS) or to use a DNS that's controlled by malicious agents.

Doxing

When hackers root out and publish personally identifying information about someone online.

Dump

The term for a trove of data released by hackers.

Dumpster diving

Hackers search through garbage looking for information that will help with an exploit. Organizations and individuals who don't consistently use a shredder are particularly vulnerable to this method.

Encryption

Using special code or software to scramble data so that it cannot be read by a third party, even if it is intercepted.

End-to-end encryption

When an encrypted message is scrambled on both ends, as it is sent and again as it is received.

Exploit

The general term for leveraging a vulnerability in a piece of code, software, hardware, or a computer network.

Firewall

A system of software and hardware that's designed to prevent unauthorized access to a computer or computer network.

Hacker

This term means different things to different people. People who tinker with code, to purposely manipulate it, are hackers. Some are good, and some are bad. In popular culture, "hacker" has taken on a reductive, distinctly negative connotation.

Hactivist

Someone who hacks for social or political reasons.

Honeypot

A system or network designed to look like a high-value target but instead built to attract hackers, watch their work, and learn from their techniques.

InfoSec

An abbreviation for "information security," InfoSec can refer to the companies and professionals who work within cybersecurity.

Jailbreak

A way of removing the restrictive manufacturer's code from a device so that you can reprogram it to function as you desire.

Keys

The code that, just like a physical key, is used to lock or unlock a system, encrypted message, or software.

Malware

Any software program that's designed to manipulate a system, by stealing information, augmenting code, or installing a rogue program. Rootkits, keyloggers, spyware, and everyday viruses are examples of malware.

Cybersecurity Terms Every Executive Should Know

Man-in-the-middle (MitM) attacks

This occurs when a hacker impersonates a trusted connection in order to steal data or information or to alter communications between two or more people. These are especially common in businesses.

Metadata

This is the data that explains what's in another set of data, such as a JPEG photo, email, or webpage.

Password managers

These third-party tools let you remember one master password to unlock a database of all your other passwords. You can still use a completely different password for every site and service you use. While password managers are a good idea in theory, many are cloud-based. If a hacker gains access to your password manager, you're in big trouble. So, if you do use

one, make sure to use a complicated password at least 36 characters long with lots of special characters, numbers, and capital letters.

Patch

An after-market fix to address technological vulnerabilities.

Penetration testing

The practice of trying to break into your own computer or network, in order to test the strength of your security.

PGP (Pretty Good Privacy)

You may have seen PGP numbers showing up in Twitter and Facebook bios. PGP is a basic method of encrypting email (and other data). In order to receive and read the message, your intended recipient must use a private key to decode it.

Phishing

We've all seen a phishing attack at least once. They usually come in the form of an email from a trusted contact. Once you open the message or attachment, your computer, your data, and the network you're on become vulnerable to attack.

Plaintext

This is text without any formatting. In the context of cybersecurity, it also refers to text that isn't encrypted.

Ransomware

This is malware that allows a hacker to break into your computer or network and then take away your access until you pay a specified fee or perform a certain action.

RAT (Remote Access Tool)

RATs are Remote Access Tools. If you've used a remote login service to access your office computer while

away from work, you've used a RAT. But RATs can be malicious, too; just imagine a hacker using a RAT to take over your workstation.

Root

The root is the central nervous system of a computer or network. It can install new applications, create files, and delete user accounts, among other things. Anyone with root access has ubiquitous and unfettered access.

Rootkit

Rootkits are malware designed for root access. Often undetected, rootkits start running when you start your computer, and they stay running until you turn your machine off.

Screen Scraper

A device or virus that captures private or personal data by logging information that is sent to a visual display.

Social Engineering

An attack that manipulates users into performing specific actions or divulging personal or account information. These threats are common in companies and often result in data breaches.

Spearphishing

A more targeted form of phishing to smaller groups, typically within social networks or work environments.

Spoofing

In general, any time data is changed to mimic a trusted source, it's being spoofed. Changing the "from" section or header of an email to make it look as though it was sent by someone else is an example of spoofing. Hackers spoof emails by impersonating people you know and then launch phishing attacks.

Cybersecurity Terms Every Executive Should Know

Verification

Ensuring that data, and its originators, are authentic.

Virtual private networks (VPNs)

VPNs use encryption to create a private channel for accessing the internet. They are necessary when connecting to public networks, including those at airports, hotels, and coffee shops.

Virus

Malware intended to steal, delete, or ransom your files. Mimicking the flu, this type of malware spreads, quite literally, like a virus.

Vulnerability

A weakness in computer software that hackers can exploit for their own gain.

White hat

Not all hackers are bad. White hat hackers work on highlighting vulnerabilities and bugs in order to fix them and protect users.

Worm

Worms are a certain kind of invasive malware that spreads like a virus.

Zero-day exploits

In the hacking community, zero-days (also written as “0day”) are prized tools because they are undisclosed vulnerabilities that can be exploited. Once the flaw is revealed, programmers have zero days to do anything about it.

Zombie

A computer, connected device, or network that's been infected by malware and is now being used by the hacker, probably without the primary user's knowledge.

How these trends impact your company



STRATEGY

The intersection of technology, policy, and politics affects every organization. As lawmakers begin to craft new types of regulations to address emerging technologies, businesses must address policy uncertainty in their long-term strategic planning. Anti-competitiveness lawsuits and antitrust investigations will have a chilling effect on merger and acquisition activity by the big tech companies. If one of the companies under scrutiny provides some (or all) of your technology stack, further improvements and features could be paused if lawsuits were to siphon off resources. Likewise, how a company collects, uses, and stores data; the technology acquisitions business units make; the vendors and partners selected; and investments made in security all affect its future. The dynamic nature of cybersecurity will directly impact corporate strategic initiatives in a variety of areas, including digital transformation, growing operating income, international expansion, and more.



INNOVATION

Policy uncertainty creates all sorts of hurdles for innovation teams. At least when it comes to the U.S. and China, both administrations have demonstrated clear, decisive plans. This should give innovation teams the foundation they need to work on new products and services related to climate change, transportation, biotech, artificial intelligence, and blockchain technologies. On the security front, those who work in innovation have a unique set of skills that could aid in a company's approach to privacy and security. One of the biggest challenges faced by companies is that they do not think creatively about adversaries or next-order outcomes. For example, before a company launches a new product, it would be useful to host a workshop to deeply investigate all of the possible ways the product could unintentionally cause harm—or bring harm to the business.



R & D

It is clear that China intends to lead the world in many areas of R&D, including AI, biotech and synthetic biology, pharmaceuticals, transportation, climate change mitigation, and space. In recent years, China has launched new programs to repatriate researchers from their U.S. and European posts. But tech companies are poaching talent also, from academic departments and other companies. With so much competition, companies should develop strategies for R&D team acquisition and retention. Security should be top of mind among R&D teams, but within many companies, R&D units struggle to keep pace with the changing technology landscape. This results in pet projects taking up too much time, even when they don't lead to desired results—or moving too quickly on projects without considering their security or privacy implications. The cadence of R&D teams must be adjusted to accommodate emerging privacy and security considerations.



GROWTH

As we continue to build our new normal—working from anywhere, dealing with security breaches, adapting to patchwork regulation—adaptability will be key to every company's ability to thrive and succeed. There are ample opportunities for growth. Companies capable of monitoring signals and trends, modeling next-order outcomes, and actively rehearsing the future will identify new opportunities to unlock growth.

Key Questions

We recommend using this report to support your strategic foresight activity in the coming year. Every executive team should begin by asking these questions:

1

- ▶ Is our company's government affairs team proactive enough, or is it simply responding to policy changes?

- ▶ In what ways might we play a role in shaping policy related to our industry's evolution?

- ▶ If our company operates in markets where a patchwork of regulations is likely to persist, how can we adapt?

2

- ▶ As a government agency, are we planning in a meaningful way for the longer term?

- ▶ Can we develop actionable, long-term plans that will withstand a change in leadership?

- ▶ As technology evolves, how will our local, state, provincial, country-level regulations keep pace without stifling innovation and growth?

3

- ▶ What parts of our business make us a target for attacks? Is there anything in our company's values, or the way we interact with consumers, that would attract the ire of hactivists?

- ▶ What might a future breach entail? Can we build scenarios in advance and anticipate our vulnerabilities?

Selected Sources

<https://www.ncsl.org/research/telecommunications-and-information-technology/2021-consumer-data-privacy-legislation.aspx>

https://ec.europa.eu/commission/presscorner/detail/en/IP_21_2663

<https://gov.edacy.com/digital-skills-initiative>

<https://postman.gov.sg/>

<https://camdx.gov.kh/>

<https://www.mci.gov.sg/>

<https://www.natlawreview.com/article/italian-ministers-announce-timetable-investment-digital-health>

<https://www.natlawreview.com/article/discovering-legal-hurdles-trying-to-protect-consumer-internet-privacy-state-maine-s>

<https://ago.vermont.gov/blog/2020/09/11/attorney-general-wins-significant-victory-in-clear->

[view-ai-lawsuit/](#)

<https://www.natlawreview.com/article/action-items-technology-and-communication-policies-front-senate-commerce-committee>

<http://wyomingbankingdivision.wyo.gov/home/areas-of-regulation/laws-and-regulation/special-purpose-depository-institution>

<https://www.americanbanker.com/news/crypto-exchange-kraken-receives-wyoming-bank-charter>

<https://www.nature.com/articles/d41586-020-03318-w>

<https://www.aas.org/programs/r-d-budget-and-policy/historical-trends-federal-rd>

<https://ncses.nsf.gov/pubs/nsb20203/cross-national-comparisons-of-r-d-performance>

<https://www.ced.org/solutions-briefs/back-to-basic-research-an-rd-invest->

[ment-plan-to-enhance-us-competitiveness](#)

<https://sgp.fas.org/crs/misc/R44307.pdf>

<https://www.gao.gov/products/gao-21-524t>

<https://www.whitehouse.gov/wp-content/uploads/2021/06/M-21-25.pdf>

<https://iapp.org/resources/article/us-state-privacy-legislation-tracker/>

<https://www.nytimes.com/2019/09/03/technology/denmark-tech-ambassador.html>

https://www.lamoncloa.gob.es/presidente/actividades/Documents/2021/140721-Carta_Derechos_Digitales_RedEs.pdf

https://www.kaspersky.com/about/press-releases/2021_ddos-attacks-in-q3-grow-by-24-become-more-sophisticated



Logistics, Robotics & Transportation

Tech trends influencing the future of the supply chain, logistics, robotics, the automotive industry and transportation.

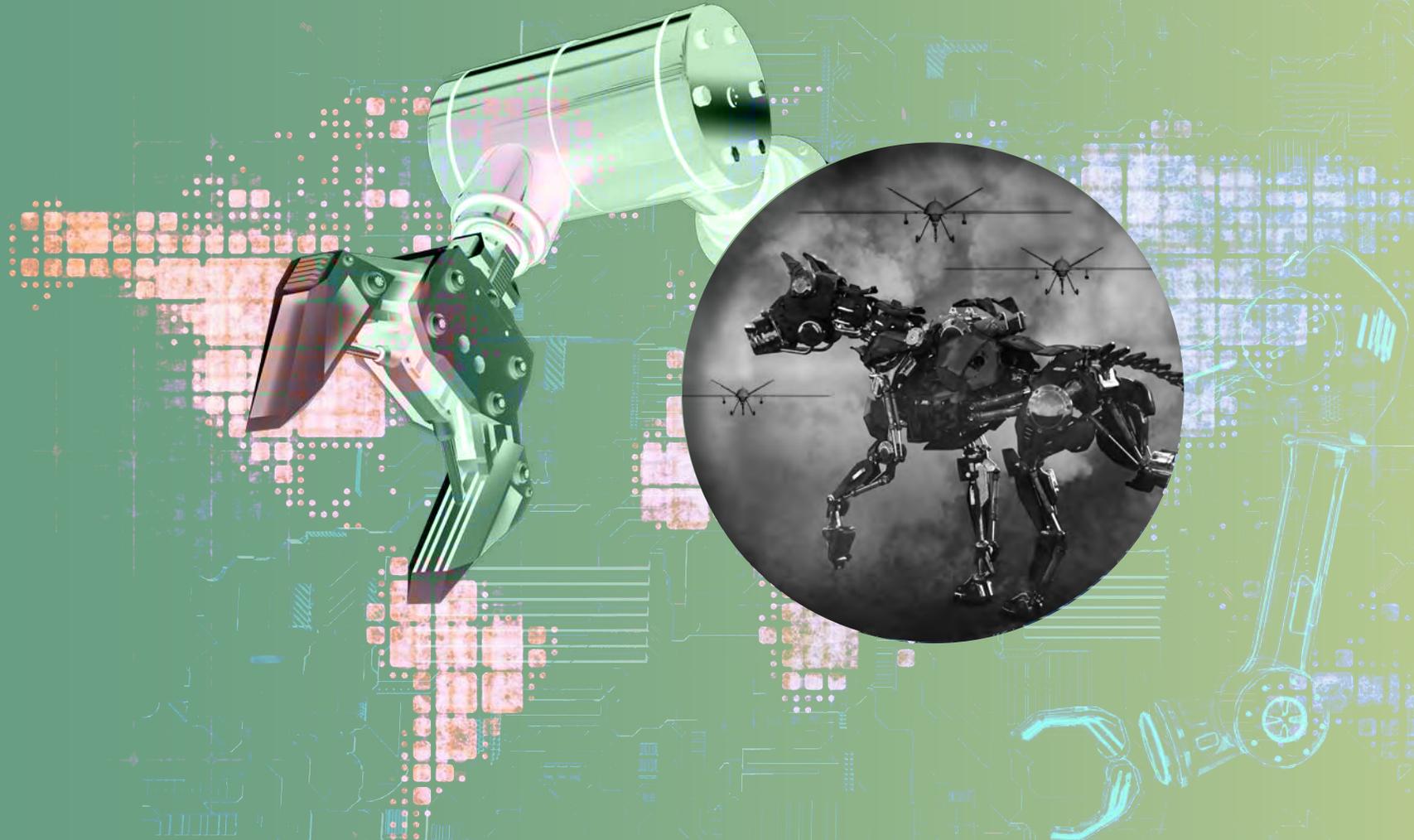


Table of Contents

397 Key Insights	422 Drones	446 Analog Fallbacks
398 Robotics	423 Drones	448 China's Global Auto Ambitions
399 Robots-as-a-Service (RaaS)	424 Drone Swarms	450 New Cityscape Designs
400 Cobots	425 Drone Fleets	451 Decarbonizing Flight
402 Autonomous Robot Swarms	427 Air Lanes	452 Foreign Infrastructure Investment
403 Self-Assembling Robots	428 Flying Taxis	454 Application
405 Robot Compilers	429 Follow-Me Autonomously	455 Key Questions
406 Soft Robotics	430 Inspection Drones	456 Selected Sources
407 Smart Dust	431 Cognitive Active Safety Features	
408 Robot Workers	433 Autonomous Last Mile Delivery	
408 Commercial Quadrupedal Robots	434 Autonomous Underwater Vehicles	
408 Mars Dogs	435 Autonomous Ships	
408 Essential Robot Workers	436 Transportation	
409 Robot Rights	437 Vehicular Biospheres	
410 Logistics & Supply Chain	438 Demand for Battery-Supported Transportation	
411 Supply Chain Fragility	439 Scenario: EV Charger Roulette	
412 Supply Chain Verification	440 Alternative Fuel Supply	
413 Scenario: The Light Way to Travel	441 EV Charging Levels	
414 Sustainability in Supply Chain and Logistics	442 Car OS	
416 Circular Economy	443 Transportation-as-a-Service Business Models	
417 Rethinking the Cold Chain	444 Exponential Growth in Autonomous Driving Data	
418 Additive Manufacturing	445 Regulating Autonomous Vehicle Testing	
419 Capturing IIOT Metadata		
420 Automating the Supply Chain		

Key Insights

- * Cloud robotics and automation are enabling the rapid scaling of robotic applications, allowing developers to test and learn, simulate, and share code in an efficient platform.
- * Early attempts at self-assembling robots mostly focused on self-reconfiguring modular robots, but new approaches are taking the capability a few steps further.
- * Soft robotics, made of flexible materials, are capable of moving in fluid ways, adapting to their surroundings, and sensing more effectively than traditional robots—and they're revolutionizing the kinds of roles a robot can play.
- * The pandemic exposed the fragility of our global supply chain. From semiconductors to shipping containers, we have seen how a single component can throw an entire supply chain into chaos.
- * From groceries to vaccines and gene therapies, the cold chain is becoming a larger part of our everyday supply chain. Investment is growing to meet rising demand for temperature-stable transit that delivers products without spoilage.
- * New significant milestones have been met and funding has increased in the area of drone fleet deliveries. Adapting federal regulations are necessary as the technology continues to make a case for its utility at scale.
- * During the pandemic, the desire for quick and contactless deliveries steadily rose, and there is little reason to think this desire will change. Consequently, autonomous delivery has become more commonplace, even pushing states to change their legislation around the technology.
- * Drones aren't just for air and land. Underwater drones have been around since the 1950s, but in recent years the technology has dramatically improved due to advanced payload offerings; low-light, high-definition cameras; enhanced seabed detection; better batteries; and more advanced sensors.
- * Accelerating adoption of battery-powered transportation is leading to a rethink of how we provide the energy required to transport people and goods from A to B, forcing our energy delivery systems to adapt to a more battery-powered and less gasoline powered transportation ecosystem.
- * More data usually results in a better algorithm, and the size of the data for training autonomous cars is accelerating at an exponential rate. In addition to the increase in real-world data from cars on the road, synthetic data is growing in volume as techniques for generating data matures.
- * The importance placed on roads is decreasing as urban planning with autonomous vehicles, sustainability, and technology is leading the charge for how urban spaces are being designed.



Robotics

4TH YEAR ON THE LIST

Robots-as-a-Service (RaaS)



AWS RoboMaker's Small Warehouse World is ideal for companies building and testing robot applications for warehouse uses.

KEY INSIGHT

Cloud robotics and automation are enabling the rapid scaling of robotic applications, allowing developers to test and learn, simulate, and share code in an efficient platform.

EXAMPLES

The field of cloud robotics and automation is rapidly expanding, with key players like Amazon Web Services launching new tools and new features on existing platforms. With each release, these platforms become more integrated, easy to use, and efficient for developers. The most recent release on AWS RoboMaker now supports container images, allowing customers to use container tools they are most familiar with. Containerization lets developers package up software code and its dependencies so that it can be run consistently on any infrastructure. AWS also released a new offering in 2021, RoboRunner, which companies can use to connect robot fleets to the cloud, manage robots in the fleet, and develop apps that optimize the operations of an automated fleet using real-time data.

DISRUPTIVE IMPACT

The rise of cloud robotics and automation is likely to drive the development of robotics for more advanced applications, such as medical robotics, which benefits from the rapid learning and improvement possible in a cloud simulation environment, as well as the remote monitoring, management, and maintenance afforded by cloud-based platforms. Expanded applications into new industries are expected to drive billions of dollars of growth in RaaS over the next five years.

EMERGING PLAYERS

- AWS RoboMaker
- AWS RoboRunner
- Cogniteam Nimbus
- Fetch Cloud Robotics
- Google Cloud Robotics
- Nvidia Isaac
- Nvidia Jetson
- Robot Operating System (ROS)

5TH YEAR ON THE LIST

Cobots



The e-Series family from Universal Robots has four members—the UR3e, UR5e, UR10e, and UR16e, which each offers a different reach and payload.

KEY INSIGHT

Collaborative robots—or cobots—have been in use across various industrial settings for years. But recent advancements in their sensors and weight limitations are enabling their use in a widening range of applications.

EXAMPLES

Cobots are intended for use alongside humans, enhancing productivity and speed and reducing risks such as error or injury. Increasingly, top cobot producers such as ABB are enhancing cobot features, making them capable of more. ABB's new GoFa CRB 15000 can handle heavier payloads, has a longer reach, and is faster than its predecessors, making it ideal for myriad applications, such as picking, packing and placing, kitting, and product handling. Universal Robots' new UR10e is similarly improved, able to handle 25% more payload, and featuring a significantly longer reach.

DISRUPTIVE IMPACT

Today, collaborative robots are primarily used in warehousing and logistics, and in manufacturing where very precise placements are required. Over the course of the pandemic, cobots were widely leveraged to overcome supply chain challenges, rapidly increasing online order and delivery demand, and staffing shortages. Universal Robots alone saw 75% growth year over year as of Q4 2021.

EMERGING PLAYERS

- ABB
- Fanuc
- Festo
- Omron
- Rethink Robotics
- Robotiq
- Universal Robots
- Vecna Robotics



That's a 25% increase in payload and a 0% increase in the price of the cobot, giving a significant boost to palletizing applications at no additional expense. That means you can move more per pick, use heavier tools, and process heavier parts, supported by the 1,300-millimeter reach (51 inches) and small footprint that makes the UR10e our bestseller.

— Joe Campbell, senior manager of applications development at Universal Robots



4TH YEAR ON THE LIST

Autonomous Robot Swarms



Moe Mamoyez (left) and Jekan Thanga, faculty members at the University of Arizona College of Engineering, have received \$500,000 from NASA to develop space-mining methods that leverage autonomous robot swarms.

KEY INSIGHT

Autonomous robot swarms are coordinated and distributed to perform complex tasks with the benefit of herd dynamics. There are a rising number of applications for this technology, mostly for environmental and agricultural purposes.

EXAMPLES

Several autonomous robot swarm startups have enjoyed strong funding rounds over the past year. Many of these companies are focused on the potential to revolutionize agriculture. Robot swarms are also uniquely suited to meet rising environmental needs, such as oil spills, endangered species monitoring, or marine emergencies, due to the quiet, noninvasive nature of drones, and the fact that they do not require a human on-site to operate them. Countless use cases for this technology abound—other startups promise swarm applications for commercial cleaning, GPS mapping, manufacturing, and completing tasks in harsh or hard-to-reach environments and underwater environments. In one recent test, part of the Defense Advanced Research Projects Agency (DARPA) OFFensive Swarm-Enabled Tactics program, an operator-directed swarm of 130 uncrewed planes, quadcopters, and ground vehicles scouted a set of mock buildings and shared information with the operator.

DISRUPTIVE IMPACT

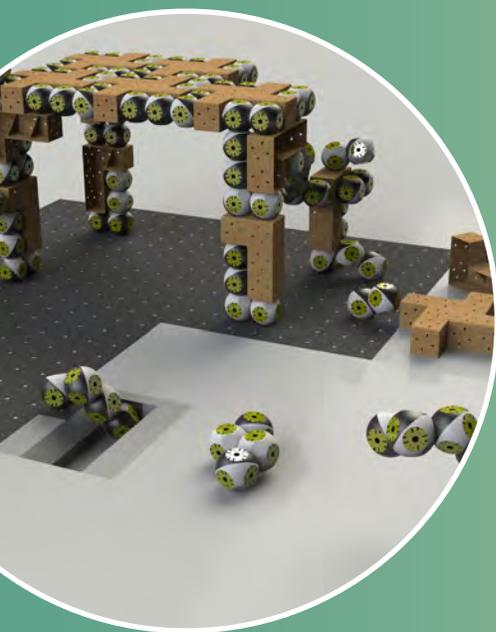
A University of Arizona team has received a NASA grant to create a new technique called the Human and Explainable Autonomous Robotic System, which leverages neuromorphic learning to train a fleet of robots on mining, excavating, and building, and enhances the robots' collaboration over time. This technique could enable the mining of materials on the moon. Undersea applications are promising as well—in 2012, Virginia Tech helped the U.S. Navy develop undersea robots that moved like jellyfish. More recently, Berkeley Marine Robotics received an innovation research grant from the National Science Foundation to conduct research and demonstrations of an autonomous underwater robot swarm system, which will perform inspections under ships. In a very different type of use case, agtech startup Aigen recently raised a \$4 million seed round for its solar-powered robotics platform, and is working to build robot swarm technology to revolutionize farming.

EMERGING PLAYERS

- Aigen
- Apium
- Avidbots
- Berkeley Marine Robotics
- DARPA
- Exyn Technologies
- Locus Robotics
- SwarmFarm Robotics
- Unbox Robotics
- University of Arizona
- Virginia Tech

4TH YEAR ON THE LIST

Self-Assembling Robots



A table is assembled by Roombots modules, using lightweight elements and integrated RB modules.

Image credit: Biorobotics Laboratory, EPFL.

KEY INSIGHT

Early attempts at self-assembling robots mostly focused on self-reconfiguring modular robots, but new approaches are taking the capability a few steps further.

EXAMPLES

Self-reconfiguring modular robot innovations include Roombots, created by EPFL (Swiss Federal Institute of Technology Lausanne), and SMORES-EP from the Modular Robotics Laboratory at the University of Pennsylvania. Now attention is turning to the newest area of discovery in the field of self-assembling robots. Martin Nisser, at HCI Engineering Group at MIT's Computer Science and Artificial Intelligence Laboratory, has partnered with the MIT Space Exploration Initiative to explore methods of using 3D printing with shape memory polymers and other smart materials to create a mechanism that will fold into its intended shape when desired. Researcher Wei Feng at Tianjin University in China, along with his team, designed a robot made of 3D-printed liquid crystal elastomer, which self-assembles by rolling into a tubular form when heated. Researchers at the University of New South Wales are developing PolyBricks, small units of DNA programmed to take a certain shape when they come together.

DISRUPTIVE IMPACT

Self-assembling robots have significant potential for the health care field. Self-reconfiguring modular robots can be used in health care settings or elder-care facilities to take the shape of needed furniture—such as a chair or a support to help someone move throughout a space. Smaller scale systems, such as nanobots, could be used in therapeutics or regenerative medicine, or to enable a targeted treatment, such as clearing buildup from an artery. Smart materials and 3D printing will enable new applications of self-assembling robots for space exploration, allowing the robots to be transported in a collapsed format, and take their needed shape upon landing. Still other applications abound for emergency response and disaster relief—self-assembling robots can take the shape of a needed escape—a shelter, bridge, or ladder—in instances such as a wildfire, flood, or earthquake.

EMERGING PLAYERS

- MIT Computer Science and Artificial Intelligence Laboratory
- MIT Space Exploration Initiative
- EPFL
- Tufts University
- University of New South Wales
- University of Vermont



Because every system launched into space has to fit within the confines of a rocket firing, space agencies are interested in structures that can self-reconfigure between smaller and larger shapes. I saw a great opportunity to build on what I'd learned about self-folding robotics. I developed algorithms that would allow large numbers of spacecraft modules to move together, attach to one another, and then reconfigure together into a target shape.

— Martin Nisser, PhD candidate, HCI Engineering Group, MIT Computer Science and Artificial Intelligence Laboratory



5TH YEAR ON THE LIST

Robot Compilers



Users of Vention MachineBuilder can design and order custom robotic equipment by choosing from modular parts and using smart design tools.

KEY INSIGHT

Robot compilers help non-engineers to conceptualize and fabricate robotic solutions, and soon they'll offer efficiencies, cost savings, and increased productivity for every industry.

EXAMPLES

We will soon tell computer systems what tasks we need completed, and they will automatically fabricate new robots for the job. The process of designing, programming, and building robots is time-intensive, and typically only achievable by engineers and robotic specialists—until recently. Institutions including the MIT Computer Science and Artificial Intelligence Laboratory and the Laboratory for Embedded Machines and Ubiquitous Robots at the University of California, Los Angeles have been working for years to develop robot-compiling solutions that make rapidly fabricated custom robots available to non-engineers. Montreal-based Vention, founded in 2016, makes it possible for users in various different industries to design robotic equipment that suits their exact needs and specifications. Users of Vention's tool can build from scratch or customize from a set of designs that cater to a number of capabilities, including inspecting and testing, machine tending, material handling, and material processing.

DISRUPTIVE IMPACT

As robot compilers continue to advance and become accessible to the average person, limited specification offerings may become less attractive to users, shifting demand to custom robots for a large proportion of the market. Robots may also be designed for an increasing number of uses, beyond where they are leveraged today. Fabricating programmable robots may not exactly be a simple, DIY weekend project, but promising research indicates that robot compilers could soon enable people with limited technical knowledge to sketch, design, fabricate, and control a robot drawn straight from their imagination.

EMERGING PLAYERS

- Laboratory for Embedded Machines and Ubiquitous Robots at UCLA
- MIT Computer Science and Artificial Intelligence Laboratory
- Vention

6TH YEAR ON THE LIST

Soft Robotics



A soft tough robot developed by the National University of Singapore is able to handle small, delicate items with care.

KEY INSIGHT

Soft robotics mimic living organisms. Made of flexible materials, they are capable of moving in fluid ways, adapting to their surroundings, and sensing more effectively than traditional robots.

EXAMPLES

Meta AI researchers have created a new kind of electronic skin and fingertip called ReSkin, a deformable elastomer with embedded magnetic particles. This soft robotic solution has enhanced tactile senses, and can perform delicate tasks more effectively than a device without the skin. Researchers at the University of California, Riverside have developed a type of light-powered soft robotic film that can be trained to remove oil spills at sea or contaminants from drinking water. A team at Linköping University took an alternative view of soft robotics opportunities, creating a soft robot that can serve as a possible bone replacement, entering the body in soft form to allow for accurate placement, and then hardening when properly arranged. Soft robots that have the ability to morph and reshape are also being developed at Southeast University in China, where researchers are modeling a soft robot after the camouflaging and self-healing properties of a starfish.

DISRUPTIVE IMPACT

Soft robots have significant advantages in handling and sensing, and are also able to mold into needed shapes that would be difficult for rigid materials to achieve. Over the coming years, soft robots may also be able to regenerate, regulate their own temperature, frequently change shape, or change level of rigidity depending on the environment. These machines could allow humans to explore previously hard-to-reach environments, take images inside of our bodies, or other extremely small areas, deliver medication in a targeted way, or take samples of their environment.

EMERGING PLAYERS

- Linköping University
- Meta AI
- MIT Computer Science and Artificial Intelligence Laboratory
- National University of Singapore
- Princeton University
- Southeast University
- University of California, Riverside

5TH YEAR ON THE LIST

Smart Dust



In May 2021, engineers from Columbia University published a study in the journal *Science Advances*, demonstrating their achievement of creating the world's smallest single-chip system ever developed, shown here resting in the tip of a hypodermic needle.

KEY INSIGHT

Smart dust, also known as microelectromechanical systems or MEMS, represents a new method of atomic-level materials engineering.

EXAMPLES

MEMS are already used today in common applications, including drone control, game controllers, digital cameras, smartphones, wearables, and pressure sensors and displays, to name a few. While these devices are not new, and have been in development for decades, recent advancements in the reduced size of computing chips as well as enhanced manufacturing methods have revealed many more purposes for MEMS.

MEMS collect data on aspects such as acceleration, altitude, and pressure, but in the coming years, the most important aspect of MEMS won't be what they collect, it will be what those devices do with the data. It's likely that in the coming years, we will see enhanced capabilities around AI/ML/DL on the edge embedded within smart dust, making it capable of not just capturing information about the environment that surrounds it but also making decisions about how to respond.

DISRUPTIVE IMPACT

Several major tech players are actively studying ways to apply microelectromechanical technology to increasingly microscopic microphone and speaker systems. Over the next several years, microphones, and inertial and optical MEMS will be the most critical devices to keep an eye on.

A subset of this field, called BioMEMS, refers to the application of MEMS in biological or health care-related applications. Several use cases are being developed that explore the use of MEMS in microscopic devices or treatments that can significantly enhance the efficacy of treatment and diagnosis while reducing the invasiveness of such procedures. Some such examples include devices that control irregular heart rhythms, enhanced microneedles for micropump drug delivery systems, "airway-on-a-chip" devices to assist in lung repair, and noninvasive methods of detecting the presence of disease or certain substances.

EMERGING PLAYERS

- Bosch
- Broadcom
- Goertek
- Google
- HP
- Honeywell
- Infineon Technologies
- Knowles Electronics
- Microsoft
- NXP
- Qorvo
- STMicroelectronics
- TDK
- TE Connectivity
- Texas Instruments

Robot Workers



Spot, a Boston Dynamics quadrupedal robot, has been implemented in a wide variety of use cases.

■ Commercial Quadrupedal Robots

A number of companies now offer quadrupedal robots, including Boston Dynamics, Ghost Robotics, and ANYbotics. MIT is also developing a smaller version of the machine called Mini Cheetah. These robots have already been implemented by companies such as National Grid, Merck, BP, and Petronas. Most quadrupedal robots in service today are used for security, monitoring, and inspections; to take readings; or for collecting images or data. Due to their agile nature, these robots can access areas that could be unsafe for human employees to enter, such as small caves or mines. They are also increasing efficiencies for businesses, which can have the robots capture images and send them to remote specialists for analysis, rather than sending specialists to various locations.

■ Mars Dogs

Current robots designed for off-planet exploration have wheels. While they're designed to roll over rugged terrain, they're limited to generally flat surfaces or gentle slopes. Scientists from NASA's Jet Propulsion Laboratory and Ames Research Center and McGill University are developing a modified version of Spot, the quadrupedal dog created by Boston Dynamics. Au-Spot, as it is known, is built for Mars: It has artificial intelligence to learn about surfaces, a communications module, and an array of sensors (thermal, visual, motion). Au-Spot should be able to climb over rocks, up steep hills, and into underground caves. These biomimetic robots will work as teams, much as human explorers do. Au-Spots, traveling in packs, will assist each other as they climb, jump, and descend on unfamiliar terrain on Mars.

■ Essential Robot Workers

During the pandemic, robots became essential workers. Fleets of automatons were deployed worldwide to assist with important tasks: They autonomously sanitized hospital rooms, remotely monitored patients, picked up and delivered prescriptions, took our temperatures, made pizzas and salads, and assisted front-line medical workers. Some robots required direct supervision, but many of them worked alone. Across North America, factories and other industrial companies hired 37% more robots than last year, valued at \$1.48 billion, according to the Association for Advancing Automation. The rush to expand the robot workforce has to do with companies struggling to keep up with demand and the enduring challenge of hiring workers for jobs that perform repetitive tasks.

Robot Workers



Quadrupedal robots can be implemented in many ways, such as situations involving a dangerous or hard-to-reach location.

■ Robot Rights

As robots are leveraged in an increasing number of settings, questions around their treatment and rights have naturally arisen. The first involves a robot's right to operate. Several states, including Pennsylvania, Virginia, Idaho, Florida, and Wisconsin, are passing rules that permit robots to operate on sidewalks, a key allowance for delivery robots. These are early signals of municipalities making legal allowances for robots to operate, but more will be needed as the machines are more widely used. The second, more disturbing concern being addressed is that of the right of a robot not to be harmed. Disturbing stories now abound of people kicking, hitting, or otherwise harming or abusing robots in public settings. In a slightly different example, many users are admitting to engaging in verbal abuse when using the AI chatbot app Replika, which simulates a human conversation.

Robots and AI-enabled chatbots cannot feel, but this is still an important area to explore. If we are teaching machines to think, and to learn from us humans, then what moral codes are we programming into our future generations of robots? How will children's interactions with robots affect the way they treat other humans around them? And perhaps, most confoundingly, but also most important—what drives humans to mistreat humanoid machines, and what does it mean for other interactions?



Logistics & Supply Chain

1ST YEAR ON THE LIST

Supply Chain Fragility



Shortages of workers, equipment, and space coupled with skyrocketing demand have exposed significant vulnerabilities in the global supply chain.

KEY INSIGHT

The pandemic exposed the fragility of our global supply chain. From semiconductors to shipping containers, a single component can throw an entire supply chain into chaos. In its World Economic Outlook, the IMF showed that shipping issues reduced global economic growth from half to one percentage point.

EXAMPLES

While chip shortages constrained traditional carmakers, Tesla was positioned to rewrite software so that it could use available chips. The electric car company could hold off many of the early impacts because much of its expertise remained in-house. However, even Tesla is beginning to feel supply chain constraints. In February 2022, sources confirmed that an electronic control unit in Chinese-built steering racks was excluded due to chip shortages. In October 2021, Amazon was reported to be acquiring refurbished long-range cargo planes so that it could better control imported products.

Companies are developing solutions to tackle these challenging conditions. Oracle has developed a new logistics management system that incorporates intelligent transit time predictions, enhanced shipment capabilities, multilingual digital assistants, and advanced global trade analytics. Attabotics provides a 3D robotic warehouse system that can help organizations to store the same amount of goods in a fraction of the floor space.

DISRUPTIVE IMPACT

For decades, business operations have focused on leaning on supply chains and incorporating just-in-time practices to reduce inventory levels. The result is a brittle supply chain with little ability to respond to fluctuations. In the U.S., the Department of Commerce issued a report highlighting that median inventories of semiconductors had fallen to less than five days in 2021. The implication is clear. In a Capgemini survey, two-thirds of organizations believed they would need to make significant changes to their supply chain strategies to adjust to a post COVID-19 world. Many were looking to add resilience back into supply chains, with 68% reporting they were actively investing in diversifying suppliers. While adding resiliency may add cost now, with rising potential for disruptions due to extreme weather and pandemics, those with the most adaptable supply chains will be best positioned to thrive.

EMERGING PLAYERS

- Attabotics
- European Chips Act
- Leaf Logistics
- Oracle

1ST YEAR ON THE LIST

Supply Chain Verification



Walmart uses blockchain technology to trace origins of over 25 products, including all leafy greens sold in its stores.

Image credit: Walmart.

KEY INSIGHT

Tracking and verifying provenance in supply chains is becoming a critical component for supply chain operations. Consumer demand for transparency combined with the need to quickly locate recalled products means companies will need to ensure they have a solution in place to meet shifting compliance requirements.

EXAMPLES

Singapore-based Zuellig Pharma launched a blockchain-based system to track and trace products like vaccines. A mobile app provides instant verification of expiration, storage conditions, and provenance. Toray Industries will launch a proof-of-concept trial of its traceability system later this year. The company seeks to provide transparency into its use of recycled materials and biomass resources. Russia's Chestny Znak ("Honest Mark") system provides details of a product's manufacturer and supply chain journey to reduce flow of counterfeit goods. To provide verification down to the individual item, luxury brands like Prada and Gucci have created unique NFTs (non fungible tokens) that enable the end customer to view a specific product's history from creation to sale. Supply chain verification isn't just for products. Codenotary allows organizations to identify and track software components across development to make it easier to identify where code libraries are being used when vulnerabilities are identified.

DISRUPTIVE IMPACT

Supply chain verification is becoming much more mainstream since early initiatives like IBM's Food Trust. The U.S. Food and Drug Administration plans to complete a rule around food traceability in November 2022 requiring the food industry to maintain records tracking data around growing, preparation, and shipping. With a rise in cyberattacks, software provenance tracking will also become critical to quickly locate known vulnerabilities in vast applications.

EMERGING PLAYERS

- Codenotary
- FDA Food Safety Modernization Act
- Gucci
- Mastercard Provenance Solution
- Prada
- TextileGenesis
- Zuellig Pharma

The Light Way to Travel • Mid-future optimistic scenario

You're eco-conscious, but you still want to travel. We get it.

Why not leave your suitcase at home? You'll lighten airplane weights and significantly reduce CO2 emissions. Plus, you won't have to worry about buying environmentally-damaging clothes.

Before you start your trip, scan your body using the Repurposeful augmented reality app. We'll capture your exact measurements and select garments that match your style, destination and itinerary.

Once you arrive at your final destination, you'll receive a customized box with one-time-use garments. When you're done wearing our clothes, drop them and the box into a Repurposeful composting bin where they'll begin their transformation into organic fertilizer for local soil production.

It's easy. It's affordable. It's the right thing to do.



Your **\$39**
styling fee
is on us.

2ND YEAR ON THE LIST

Sustainability in Supply Chain and Logistics



Companies are increasingly using QR codes to provide information to consumers about the sustainable practices embedded throughout the entire supply chain of a given product.

KEY INSIGHT

Regulations and shifting market expectations are pushing companies to improve sustainability of their supply chains. From apparel to food to construction, calls for action mean companies not only have to transform supply operations but provide reporting that verifies claims.

EXAMPLES

In January 2022 Fashion for Good launched the D(R)YE Factory of the Future, a project to accelerate the shift from wet to mostly dry material processing. The program claims that innovations including plasma and laser treatments, spray dyeing, and foam dyeing have the potential to reduce emissions by up to 89% and cut water consumption by up to 95%. The Roundtable on Sustainable Palm Oil developed a set of environmental and social criteria that companies must comply with for certification and has over 5,000 members, including General Mills and Kellogg. Cargill invested \$200 million in a new refinery in Indonesia that guarantees traceability to the plantation where raw palm oil is sourced.

Many companies are leveraging QR codes on their packaging to connect consumers with easy-to-access information about the product's provenance and history. These codes provide buyers with information about the item's sustainability-related information.

DISRUPTIVE IMPACT

Sustainability regulation is shifting. Across the European Union, the proposed Corporate Sustainability Reporting Directive seeks to reduce variability in reporting practices and require all large EU and EU-listed companies to report on sustainability. The first set of standards would be adopted by October 2022. In Germany, a new law was passed in June 2021 that fines companies directly if their suppliers breach human rights or environmental rules, making companies responsible for their entire supply chain, from raw materials to finished products. If passed, The Fashion Sustainability and Social Accountability Act would require global apparel and footwear companies operating in New York to set binding targets to reduce environmental impact, map their complete supply chain, and comply with mandatory reporting. It won't be enough to sign onto sustainability pledges; companies will need to prove they are acting and producing results.

EMERGING PLAYERS

- Higg Product Module
- The Fashion Sustainability and Social Accountability Act
- o9 Solutions
- Fashion for Good
- EU Corporate Sustainability Reporting Directive
- Linking Environment and Farming (LEAF) Marque
- Centric PLM
- EcoVadis
- Covalent Fashion
- U.S. Cotton Trust Protocol



We believe that we must protect the planet and the future of sport, by creating, testing, and building momentum around consumer and operational solutions that address the issues we face relative to carbon, waste, water, and chemistry.

— Andrew Campion, Nike chief operating officer



1ST YEAR ON THE LIST

Circular Economy



Companies are looking for opportunities to recycle or reuse materials that decrease their environmental impact—especially in the fashion industry.

KEY INSIGHT

Sustainability commitments by governments, combined with emerging customer expectations, are driving growth of startups and investment by brands in the area.

EXAMPLES

Adidas' Choose to Give Back program rewards people for donating old apparel, accessories, and shoes in any condition and from any brand. The sports brand resells items in good condition and reuses remaining materials. Nike takes damaged shoes and refurbishes them by hand for resale in selected markets. The EU has been leading many efforts around the circular economy. The EU-funded Circular System for Assessing Rare Earth Sustainability uses blockchain tokens and digital passports to track rare earth metals and certify compliance with global standards. With the increased electrification across the continent, securing this supply chain is critical for the economy. In France, an anti-waste law aims to recycle all plastics by 2025, introduce a “repairability index” that rates the ease of repairing products before they are purchased, and plans to hold makers of goods responsible for their products when they are thrown away.

DISRUPTIVE IMPACT

Investment in circular economy startups is accelerating as brands invest in their own entry into resale. New models are emerging like subscription-based clothing company Circos, which lowers the environmental impact of apparel during the first few years of a child's life by providing larger sizes as the child grows and recycling the items that no longer fit. As countries begin to hold manufacturers responsible for product waste at end-of-life, product designs and business models will need to adapt. Dubai recently increased the cost of waste disposal to drive greater reuse and recycle of materials. Renault's circular economy factory Re-Factory is part of the company's strategy to achieve zero impact by 2050. All companies will need to consider their entire value chain and how they can make changes to manufacturing practices and product use that extends end-of-life through repair, reuse, and recycling.

EMERGING PLAYERS

- Resortecs
- Circolor
- The Ellen MacArthur Foundation
- Circularise
- Mercari
- ThredUP
- Circos
- Vietnam's revised Law on Environmental Protection
- Mediolanum Circular Opportunities fund

3RD YEAR ON THE LIST

Rethinking the Cold Chain



Making the cold chain more efficient and effective is a challenge many logistics companies are rising to meet.

KEY INSIGHT

From groceries to vaccines and gene therapies, the cold chain is becoming a larger part of our everyday supply chain. Investment is growing to meet rising demand for temperature-stable transit that delivers products without spoilage.

EXAMPLES

UPS leveraged vaccine experience gained during the pandemic to develop a permanent end-to-end offering through its health care division. The logistics company tracks temperature diversions from its command centers and touts 99.9% on-time delivery. UPS also worked with Atrium Health Wake Forest Baptist to deliver vaccines using its Flight Forward drone service while maintaining cold chain requirements. Research led by the University of Hawaii at Manoa demonstrated use of supercooling to extend the shelf life of asparagus without damaging it, an innovation that may be used with other produce to keep it fresh for longer periods. Passive thermal packaging introduced by World Courier maintains low-frozen temperatures for up to 168 hours. These Cocoon shipping containers are also 30% lighter than traditional containers. A personal cooler-size ultra-low temperature freezer created by Stirling Ultracold maintains temperatures while using a third of the power required by compressor-based containers.

DISRUPTIVE IMPACT

Global spending on biopharma cold-chain logistics is expected to reach \$21.3 billion by 2024, according to the 2020 Biopharma Cold Chain Sourcebook, and we are already seeing this rise in investment today. American Airlines Cargo doubled its cold-chain capacity while UPS launched a permanent service offering and expanded its global cold chain network. DHL announced plans to invest \$400 million in 2022 to expand its pharmaceutical and medical supply capabilities in the U.S. Results from the 2022 Third-Party Logistics Study found that both shippers and third-party logistics companies are accelerating growth plans to develop more cold chain capacity. Part of that may include automating pallet storage and retrieval as well as order picking to increase efficiency and eliminate the need for employees to work in harsh conditions. Reusable thermal packaging and passive packaging are other areas of innovation being explored to drive down costs while improving performance and sustainability.

EMERGING PLAYERS

- UPS Cold Chain Solutions
- World Courier
- Stirling Ultracold
- DHL

11TH YEAR ON THE LIST

Additive Manufacturing



Experiments on the International Space Station demonstrated the feasibility of bioprinting organs in low gravity environments.

Image credit: NASA.

KEY INSIGHT

Once constrained to simple polymers, additive manufacturing (AM)—or 3D printing—has expanded to use metal, ceramics, and biological materials. New technologies are pushing the field beyond geometric, surface quality, and material limitations to create optics, shape-morphing materials, and self-healing components.

EXAMPLES

Advances in AM are opening new possibilities in medicine and off-planet manufacturing. In 2021, 11% of NASA's Small Business Innovation Research and Small Business Technology Transfer grants leveraged additive technologies. NASA's focus on in situ resource utilization makes additive a key enabling technology. But there are other advantages to zero-gravity environments—such as printing large delicate structures, like chambers of a heart. Researchers at Tel Aviv University are using 3D printing to replicate brain tumors from a patient's tissue to optimize drug treatments and target proteins and genes for that patient's tumor. The next-generation bioprinter in development by nScript is a bioreactor that integrates spinning, shaking, and oxygen infusion to achieve similar results outside of low-gravity environments. Additive is gaining traction in home construction where it is used to print exterior walls that reduce time and cost compared with traditional wood-frame homes.

DISRUPTIVE IMPACT

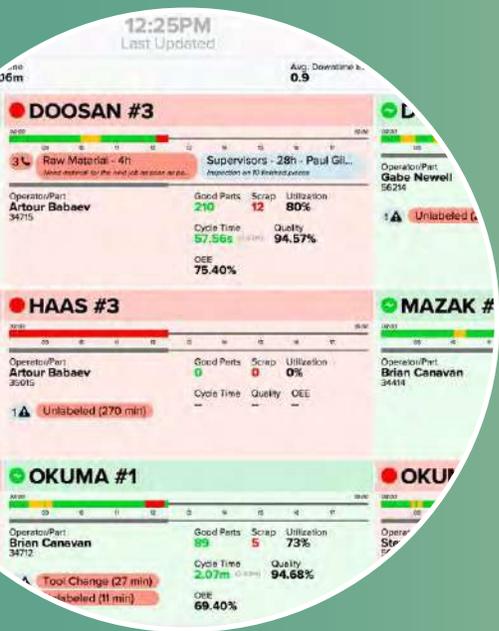
AM is rapidly growing, in part, due to a global focus on sustainability and reshoring initiatives. It is powering the rise of microfactories that localize production while offering remanufacturing techniques that create seamless repairs for damaged components. Outside of traditional applications in aerospace, automotive, and heavy industry, medical applications are growing. As of 2021, the U.S. Food and Drug Administration had cleared over 100 devices manufactured using additive technologies. As the technology grows, organizations should consider Design for Additive Manufacturing practices that move beyond traditional manufacturing constraints. Regulation has been slowly developing but will need to address key issues in intellectual property and quality assurance while organizations like the Pacific Northwest National Laboratory are exploring national security implications.

EMERGING PLAYERS

- 3D Systems
- Alquist 3D
- BioLife4D
- Carbon 3D
- ExOne
- Stratasys
- Formlabs
- ICON
- Lund University
- Materialise
- Mighty Buildings
- NScript
- University of Toledo Institute of Applied Engineering Research
- World Economic Forum's Industrializing Additive Manufacturing Initiative
- Xi'an BLT

5TH YEAR ON THE LIST

Capturing IIoT Metadata



KEY INSIGHT

The industrial internet of things (IIoT) deploys sensors that monitor the conditions of industrial machines and systems. Metadata provides additional context to the data collected such as sensor functionality, placement, and relationship within the network. It's this metadata that holds the key to unlocking value from massive amounts of data.

Manufacturers use Amper's machine monitoring system to monitor machine performance in real time and identify bottlenecks.

EXAMPLES

Large troves of data are being generated by sensors and connected devices in industrial settings. Industrial operations look to that data to provide insights around cost savings, efficiencies, and process deviations. With the rise of cloud-based AI, metadata enables multipurpose solutions that can adapt to the operational context of the data without having to be familiar with an equipment's specific operation. Today's solutions offer live, real-time dashboards so that leaders can monitor production process and machine condition, to identify opportunities for predictive maintenance or process optimization.

DISRUPTIVE IMPACT

The Open Platform Communications Unified Architecture attempts to provide a standard for data exchange between machines and platforms. This standard was broadened in the late 2000s to cover more of the machinery landscape, and is still in use today. Data management has gone from a voluntary nice-to-have to an absolute requirement on manufacturing and warehouse floors. Enhanced metadata management in industrial settings enables businesses to improve their margins, decrease scrap, reduce downtime, increase the quality of their output, and become more efficient. As AI capabilities expand into this space, deeper and less obvious insights will emerge, allowing organizations to truly leverage their machinery to the fullest extent.

EMERGING PLAYERS

- Amper
- Augury
- MachineMetrics
- Plataine
- PTC ThingWorx
- Uptake

3RD YEAR ON THE LIST

Automating the Supply Chain



Kroger is leveraging automated micro-fulfillment centers to provide rapid fulfillment in areas where it doesn't have retail stores.

Image credit: Kroger.

KEY INSIGHT

Rising inflation and labor challenges are accelerating adoption of automation. Less than a tenth of U.S. warehouses are heavily automated, but as supply chain velocity increases, robotics can increase productivity and lower costs. Artificial intelligence provides more accurate predictions of demand while wearables bring intelligence to logistics workers based on context.

EXAMPLES

Automated technology is bringing expanded capabilities while lowering implementation costs. In December 2021, Tyson Foods announced it would spend \$1.3 billion over the next three years to automate its production lines. Struggling to keep its production plants staffed, the meat giant plans to invest over \$500 million in this next fiscal year alone and expects to recoup \$450 million in cost savings by 2024. Tyson isn't alone. Logistics company ArcBest modified Phantom Auto forklifts for autonomous operation with remote human operators looped in for complex tasks. Nike is investing in demand-sensing AI to predict, plan, and shape individual consumer demand. The company has added over 1,000 collaborative robots to its distribution centers that sort, pack, and move inventory. Walmart announced it is installing automated material handling systems in its regional distribution centers. Grocer Kroger opened its third automated fulfillment center in February 2022 to support expansion of e-commerce initiatives.

DISRUPTIVE IMPACT

The National Bureau of Economic Research reported that the pandemic left almost 600,000 logistics jobs unfilled just in the U.S. As companies continue to face logistics worker shortages, automation is becoming much more attractive. Retail operator Fast Retailing plans to open an automated warehouse in China by August 2022. It was able to reduce its workforce by 90% after automating one of its Japanese facilities in 2018. Across China, automation is accelerating to adjust for an aging population. By 2025, the country expects to have at least 500 smart manufacturing factories. Globally, money is flowing into supply chain automation. PitchBook reports that supply chain technology startups raised \$24.3 billion in venture funding in the first three quarters of 2021. The expectation is that by injecting automation, AI, and machine learning, lean supply chains will develop greater resiliency.

EMERGING PLAYERS

- ArcBest
- AutoStore
- Einride
- Exotec
- Flock Freight
- Loadsmart
- Ocado Group
- Phantom Auto
- Project44



**By 2025, 52% of current workplace tasks
will be automated.**

—DHL's "Future of Work in Logistics" report





Drones

11TH YEAR ON THE LIST

Drones



Aerial and ground-based drones are showing significant promise in agricultural applications.

KEY INSIGHT

The global drone market continues to see unprecedented rise, and is expected to grow from a \$15 billion market in 2020 to more than \$90 billion by 2030, bolstered by its wide-ranging applications in defense, public safety, agriculture, weather monitoring, and enterprises.

EXAMPLES

Drones, or unmanned aerial vehicles (UAVs), carry out tasks that range from the mundane to the extremely dangerous, including firefighting efforts. Other types of drones are not limited to aerial activities but travel across terrain or below the ocean. Japanese telecommunications operator KDDI, in partnership with Prodrone and Qysea, has developed the first “sea-air integrated drone.” This drone is capable of aerial navigation, and it is equipped with an underwater drone payload that can be released once the craft has made contact with water. The Pentagon’s Defense Advanced Research Projects Agency (DARPA) raised the stakes for UAVs by equipping an UH-60A Black Hawk helicopter with Sikorsky’s Matrix technology. This technology allows preexisting aircraft to be equipped with individualized autonomous systems from scratch. This breakthrough could allow the military to operate aircraft at all times of the day or night—and begin to redefine what has the potential to be operated remotely or autonomously.

DISRUPTIVE IMPACT

Adoption of drones will continue to expand over the coming years, allowing companies and organizations of all types to access hard-to-reach areas for uses such as search and rescue, optimized and speedier delivery, increasingly efficient warehouse and agricultural operations, and climate monitoring.

While drone technology has been around for sometime, regulators have not found a way to safely integrate the technology. However, in June 2021, the U.S. Federal Aviation Administration announced that it had created a new rulemaking committee focused on UAVs that operate beyond visual light of sight. This committee is made up of 86 organizations, including six drone manufacturers. This collaboration between the drone industry and regulators will result in recommendations that will take effect in two to three years. The impact could result in the implementation of drones at scale, providing a broad range of services.

EMERGING PLAYERS

- 3D Robotics
- AgEagle
- Alpine 4
- Ambarella
- Autel Robotics
- Boeing
- DJI
- DraganFly
- GoPro
- Hubsan
- Lockheed Martin
- Parrot SA
- Red Cat Holdings
- Vuzix
- Yuneec

6TH YEAR ON THE LIST

Drone Swarms



Raytheon is working under a contract for the Pentagon's Defense Advanced Research Projects Agency to build unmanned aircraft system platforms that work together in formations, enabling swarms of drones that can overwhelm adversaries and fly into dangerous locations.

KEY INSIGHT

Drone swarms, or fleets of networked drones capable of coordinated operations and communication, are expanding the capabilities of a single operator. As this technology advances, swarms will be able to operate with no human interaction, allowing the collective functionality of the entire network to take precedence over any single drone.

EXAMPLES

Raytheon has developed a system that lets a single user operate a swarm of 130 physical drones as well as 30 simulated drones at the same time. With this technology, an operator could control these drones in air-based or land-based situations, inside or outside, with minimal training. The Israel Defense Forces used a swarm of small drones to attack Hamas militants. While drones have been used before in combat, this is believed to be the first instance involving a swarm. The drones supplied by Elbit Systems enable a single user to operate the craft almost silently to provide persistent observation or deliver explosives. Drone swarms have been used in other unique ways: India used drone swarms to decorate the night skies with formations of the national flag and Mahatma Gandhi. In China, Bilibili flew a fleet of 1,500 drones to create a QR code advertisement promoting the video game Princess Connect! Re:Drive.

DISRUPTIVE IMPACT

Semiautonomous drone swarms, such as the ones highlighted by Raytheon and Elbit Systems, drastically expand the capabilities of single users, equipping them with the power of more than 100 drones that can work in concert to achieve a unified task or goal. As semi-autonomous drones become more fully autonomous, the implications grow even more significantly, with AI being able to complete tasks, even if drones are lost during a mission, by calibrating other drones in the swarm to cover the slack. While the swarm remains minimal, only consisting of four separate drones, Korean Air has implemented the use of drone swarms to conduct inspections on aircraft. Collision-avoidance systems and geofencing enable such tasks and result in a 60% reduction in time spent by human inspection. As the technology scales, fully autonomous swarms will grow in size of fleet and level of application.

EMERGING PLAYERS

- Raytheon
- Elbit Systems
- Korean Air
- Northrop Grumman
- Israel Aerospace Industries
- Lockheed Martin
- China Aerospace Science and Technology Corp.
- BAE Systems
- Boeing

3RD YEAR ON THE LIST

Drone Fleets



Significant growth in online shopping and home delivery has created possible new areas of opportunity for drone delivery.

KEY INSIGHT

New significant milestones have been met and funding has increased in the area of drone fleet deliveries. Adapting federal regulations are necessary as the technology continues to make a case for its utility at scale.

EXAMPLES

While early applications of possible drone fleets were tied to pizza deliveries, the idea is coming full circle as Domino's Pizza has partnered with Skydrop to advance drone delivery trials in New Zealand. 7-Eleven is an unexpected candidate for adopting drone deliveries, but the convenience store has partnered with All Nippon Airways to really expand its convenience offerings to be available 24 hours a day, 365 days a year. Alphabet's drone fleet service, Wing, has reached a new milestone of completing over 100,000 deliveries, operating in Australia, the U.S., and Finland, as the technology still aims to prove its utility at scale. The Israeli startup Flytrex, which has partnered with Walmart to target suburban consumers, has raised \$40 million in funding while it waits for expanded regulatory permissions to expand to new markets. Retailio has piloted the technology to deliver medicine to Indian hospitals, while Nebo conceptualizes using it to create a fleet of hovering remote charging stations for electric vehicles.

DISRUPTIVE IMPACT

Drones offer the promise of truly meeting end users wherever they are. Demand for contactless deliveries stemming from the impacts of COVID-19 have caused projections for global drone package deliveries to grow from \$0.68 billion to \$0.99 billion with a compound annual growth rate of 44.5%, with the market expected to raise to \$4.4 billion by 2025. Drones are merely the conduit between service provider and end user. As regulations adapt and the technology improves, fleets will provide more than just the delivery of products but will also be used to offer various services, such as health-related assistance to distressed individuals in remote locations.

EMERGING PLAYERS

- Alphabet Wing
- Amazon
- Skydrop
- All Nippon Airways
- Flytrex
- Walmart
- 7-Eleven
- Redwing Labs
- Retailio
- Nebo



Every breakthrough business idea begins with solving a common problem. The bigger the problem, the bigger the opportunity. I discovered a big one when I took apart an IBM PC. I made two interesting discoveries: The components were all manufactured by other companies, and the system that retailed for \$3,000 cost about \$600 in parts.

— Michael Dell, founder, chairman and CEO of Dell Technologies



6TH YEAR ON THE LIST

Air Lanes



The FAA will need to continue building regulation around airspace use and air lanes as aerial unmanned aircraft become increasingly common.

KEY INSIGHT

As applications for drones become more pervasive, aviation guidelines and regulations for operating these vehicles will become increasingly necessary. Essentially, a system of “air lanes” will establish a guide for both piloted and autonomous low-flying aircraft. Managing the number of flying drones will be important to ensure safety and minimize noise pollution.

EXAMPLES

Traditionally, air traffic control measures for drones have relied on government agencies. This remains largely the case, as the U.S. Federal Aviation Administration has made regulatory developments over the past year including the BEYOND program, the Operations Over People program, and remote ID regulations. The FAA is not the only organization to develop mobile applications to inform recreational users where they can and cannot operate drones. Alphabet Wing has also developed its own drone safety and navigation app called OpenSky. Airbus is another commercial operator with plans to impact this domain by collaborating with regulators, manufacturers, service providers, and consumers to build air traffic management tools and solutions for air taxis and delivery drones. Israel has taken even more progressive measures by becoming the first country to allow large, high-flying drones in civilian airspace.

DISRUPTIVE IMPACT

Currently, regulations related to the management of unmanned aerial vehicles are piecemeal. At present, there are no rules that all countries agree on relating to the operation of drones. Development of international drone rules and regulations would be an expedient, albeit challenging measure to be taken, such as how the International Civil Aviation Organization rules global air traffic now. Regulators still have the opportunity to take preemptive measures to minimize congestion, ensure safety and privacy, manage community perception, and learn from road and air travel; however, that timeline is quickly shrinking as more commercial and noncommercial drone applications develop. Partnerships among government agencies and private companies will be required to keep air lanes operational and safe.

EMERGING PLAYERS

- U.S. Federal Aviation Administration
- International Civil Aviation Organization
- EU Aviation Safety Agency
- Civil Aviation Administration of China
- South African Civil Aviation Authority
- Civil Aviation Authority of Singapore
- Israel's Ministry of Transport and Road Safety
- Air Traffic Control The Netherlands (LVNL)
- Airbus UTM
- Alphabet Wing
- Hyundai's Urban Air Mobility

4TH YEAR ON THE LIST

Flying Taxis



Flying taxis could improve short range transportation and help to ease traffic congestion in major metropolitan cities.

KEY INSIGHT

While vertical take-off and landing (eVTOL) aircraft may only result in the transportation of small groups of individuals over short distances, the positive impacts on traffic congestion, civic design, and city planning are paramount. As concepts have moved to the testing and prototyping stages, the true potential of this technology will be more fully realized.

EXAMPLES

Joby Aviation is conducting a series of eVTOL flights over San Francisco Bay, according to documents filed with the U.S. Federal Communications Commission. Tests of its prototype, the S4, would be the first in an urban environment in full view of the public. Such tests naturally follow other milestones the company reached this past year, setting the record for the longest flight (155 miles) the fastest flight (205 mph) and the highest flight for an eVTOL aircraft. The Japanese company Aix has preordered 50 units of Ehang's EH216 AAVs. As Ehang emerges as a significant player in the urban air mobility (UAM) sector, its air taxis will be operational by 2025 or the World Expo in Osaka. Networks of flying taxis will require more than just the eVTOL technology required to power the flights. Australian based Skyportz is seeking partnerships with underused parking garages to build infrastructure for vertiports for these eVTOL air taxis.

DISRUPTIVE IMPACT

While the viability of flying taxis still comes into question, as the industry gains momentum and investors designated \$4.3 billion for electric air taxi startups last year, city, regional, and state officials will be forced to make concessions for such new ways of transportation. And that is not to say that public agencies have not already made movements in this area. NASA launched its Advanced Air Mobility National Campaign with the objective of partnering with other government and state agencies as well as industry leaders. The city of Los Angeles is particularly interested in air taxis to assuage local transportation issues and has developed programming from the mayor's office to develop a policy toolkit to advance such operations. As public agencies invest more time and energy in this space, this new mode of travel could have impacts on civic design and infrastructure.

EMERGING PLAYERS

- Joby Aviation
- Ehang
- Autonomous Flight
- Skyportz
- Lilium
- Airbus
- Tetra
- Urban Aeronautics

5TH YEAR ON THE LIST

Follow-Me Autonomously



Follow-me drones have a variety of uses, including photography, videography, safety, and monitoring.

KEY INSIGHT

“Follow-me” functionality allows a drone to detect and pursue a moving subject, and has myriad applications ranging from photography and videography to security and safety.

EXAMPLES

Many photo- and video-enabled consumer drones available today have “follow-me” and crash-avoidance functionality, enabling semiautonomous flight, where a subject is kept in the frame of the camera without the need for a designated pilot. These drones rely significantly on two types of technology: vision recognition and GPS. Vision recognition provides the most advanced version of obstacle detection and avoidance. Qualcomm is integrating 4K and 8K cameras into its drones, greatly enhancing this skill of obstacle avoidance. GPS allows drones to follow a transmitter signal of an associated remote control. Jeep is planning to incorporate a follow-me function into its platform, enabling a drone to follow the vehicle for the purpose of capturing photos of the subject or providing additional lighting for navigating dark, off-road trails. Piaggio Fast Forward has released the Gitamini, a robot that uses cameras, sensors, and radar to follow its users on land.

DISRUPTIVE IMPACT

As vision recognition for drones improves, the ability to automatically avoid crashes and reroute around obstacles will also improve, greatly increasing the drone’s safety and versatility. Autonomous conflict avoidance and follow-me functionality reduce stress and sensory demand on the remote pilot, allowing him to concurrently operate other tasks. These factors also make indoor flight easier and expand the range of circumstances in which drones can be safely operated. While follow-me functionality has primarily been used for capturing photos of a subject, the technology could be used for other situations, such as providing auxiliary light, making it possible for the Glowglobes represented in “Dune” to become a reality.

EMERGING PLAYERS

- DJI
- Gitamini
- Jeep
- Yuneec

4TH YEAR ON THE LIST

Inspection Drones



An inspection drone examines power lines for issues or malfunctions.

KEY INSIGHT

As natural disasters and extreme weather become more common, drones will not only provide more insight and advanced detection of destructive weather events but also help with the rapid inspection and analysis of critical infrastructure.

EXAMPLES

Industries that require visual inspections are increasingly turning to drones to perform such tasks. More recently, power utilities have moved in this direction, equipping drones with zoom lenses, thermal sensors, and lidar to capture more information about power lines and infrastructure. Researchers from the University of Kentucky are exploring the possibility of using unmanned aerial vehicles to assist cattle producers by remotely locating cattle and assessing herd health. Drones and machine learning are being used by NOAA's National Centers for Coastal Ocean Science and Oregon State University to identify marine debris that has accumulated along coastal regions. In a partnership with Black Swift Technologies, NASA is using rugged drones to monitor active volcanoes and warn of potential eruptions.

DISRUPTIVE IMPACT

As extreme weather events become more frequent and destructive, additional strain will be placed on existing infrastructure. Inspection drones will not only be used to monitor and inspect natural disasters, but they will also be used to gain access to difficult-to-reach, at-risk infrastructure such as gas pipelines and power lines.

EMERGING PLAYERS

- NASA
- Black Swift Technologies
- University of Kentucky
- NOAA's National Centers for Coastal Ocean Science
- Oregon State University
- Buzz Solutions

4TH YEAR ON THE LIST

Cognitive Active Safety Features



Backup cameras and blind spot monitoring have gone from luxury accessories to safety staples.

KEY INSIGHT

Car manufacturers are racing ahead to develop proactive safety functions and semiautonomous capabilities to satisfy both consumer and regulator demands.

EXAMPLES

The Insurance Institute for Highway Safety announced in early 2022 that it would release its first ever safeguard ratings for partial automation technologies later in the year. The ratings, which will score capabilities as good, acceptable, marginal, or poor, are meant to provide drivers with greater clarity around these safety features' effectiveness. This announcement comes as safety features such as Front Automotive Emergency Braking, Blind Spot Warnings, and Rear Cross Traffic Warnings are increasingly common in new vehicles.

While autonomous vehicle frontrunner Tesla continues to improve its self-driving capabilities, key auto players including Nissan, Chrysler, Toyota, Mazda, Honda, and Hyundai have implemented top-of-the-line safety systems. Other companies are making strides in the space as they develop new cutting-edge technologies. Netradyne specializes in AI-powered dash cameras while Comma.ai created Openpilot, an open-source software driver assistance program.

DISRUPTIVE IMPACT

Despite these safety features, car accidents have continued to spike over the past two years, owing to increased speeding as drivers take advantage of the decreased traffic congestion during the pandemic. Cars on U.S. roads are also fairly outdated, and likely don't have many of these safety systems installed, as the average age of U.S. vehicles reaches a peak of 12 years. As more individuals buy newer cars, and a greater number of vehicles on the road have such cognitive safety features embedded, road safety will likely increase significantly.

Vehicle manufacturers will continue to implement and tout active safety features to attract safety-minded consumers and appease regulators, as software drives the next wave of advancements. Car manufacturer development cycles, which historically span about 10 years, will naturally accelerate as platforms and vehicles become increasingly software driven and technologically complex.

EMERGING PLAYERS

- Chrysler
- Comma.ai
- Honda
- Hyundai
- Insurance Institute for Highway Safety (IIHS)
- Mazda
- Netradyne
- Nissan
- Tesla
- Toyota

Partial automation systems may make long drives seem like less of a burden, but there is no evidence that they make driving safer. In fact, the opposite may be the case if systems lack adequate safeguards.

— IIHS President David Harkey

4TH YEAR ON THE LIST

Autonomous Last Mile Delivery



Small road-based autonomous drones are enabling faster and more efficient last mile delivery, especially of small items like meals or groceries.

Image credit: Starship Technologies.

KEY INSIGHT

During the pandemic, the desire for quick and contactless deliveries steadily rose, and there is little reason to think this desire will change. Consequently, autonomous delivery has become more commonplace, even pushing states to change their legislation around the technology.

EXAMPLES

Starship Technologies, the autonomous delivery company consisting of a fleet of small six-wheeled robots, experienced impressive growth during the pandemic. By early 2021, the company had already achieved 1 million deliveries, experiencing a 900% increase in deliveries from where it had been mid-2019. By late 2021, Alibaba Group's autonomous delivery robot program had achieved the same milestone in China; however, this happened only a year into its operation. The efficient system employs 200 robots carrying parcels to 200,000 consumers in 52 cities spread out over 22 provinces. As companies look to improve this technology in an effort to safely reach more customers, the Polytechnic University of Catalonia and CARNET have developed delivery robots that are capable of going up and down stairs. Autonomous delivery company Nuro announced its next-generation vehicles will be equipped with an external airbag for protecting pedestrians.

DISRUPTIVE IMPACT

As autonomous last mile delivery gains momentum, legislation has already adapted accordingly. The state of Pennsylvania has gone as far as recognizing delivery robots as pedestrians. They can weigh up to 550 pounds and drive up to 12 mph to maintain this designation. Proponents of these measures suggest that they will bring about a future where household items are delivered in no time, reducing the amount of bulky delivery vans that block sidewalks and produce harmful emissions. The consultancy MarketsandMarkets projects that this industry will grow to \$4.9 billion by 2030 and could reduce delivery costs for the retail industry by up to 90%. As autonomous deliveries become more commonplace, they will serve as a reliable, data-rich, and cost-effective solution for last-mile transportation. Additionally, they could create conditions that lead to autonomous vehicle systems for transporting people becoming more palatable to the general population.

EMERGING PLAYERS

- Starship Technologies
- Alibaba Group
- Nuro
- Wayve
- Loggi Tecnologia
- StreetDrone
- DroneUp
- Tiny Mile
- Coco

5TH YEAR ON THE LIST

Autonomous Underwater Vehicles



The autonomous underwater vehicle Fetch in the waters of the Caribbean.

Image credit: M. Dale Stokes.

KEY INSIGHT

Drones aren't just for air and land. Underwater drones have been around since the 1950s, but in recent years the technology has improved dramatically due to advanced payload offerings; low-light, high-definition cameras; enhanced seabed detection; better batteries; and more advanced sensors.

EXAMPLES

Some of these underwater craft remain tethered to external inputs or are remote operated, others are becoming more autonomous and independent. Autonomous underwater vehicles (AUVs) can now accommodate a range of payloads. They can be equipped with underwater cameras, sonars, and even sniffing sensors capable of detecting chemicals and other particles. While Anduril, the startup operated by Oculus' co-founder Palmer Luckey, has primarily focused on above-ground drones, it is shifting its focus to AUVs with the acquisition of Dive Technologies. These services can already engage in anti-submarine warfare, mapping of seabeds, and oceanographic sensing. Notilo Plus' AUV, the Seasam, uses acoustic and computer vision technologies to wirelessly follow and capture HD video of its scuba-diving user. The technology recently gained recognition after being featured in the horror film "The Deep House."

DISRUPTIVE IMPACT

Various driving factors are contributing to this market's estimated \$3.71 billion worth by 2026. These include the rising demand in the defense sector, the increased demand for search and discovery of ship wreckage and air crashes, advancing capabilities for seabed mapping, and its application for coastal protection, intelligence, and surveillance. Additionally, AUVs have the potential to lessen the environmental impact of operations at sea and the ability to produce sustainable offshore data acquisition services. As military bodies seek to expand both offensive and defensive capacities and enhance intelligence, network infrastructure, and port security, AUVs will provide cost-effective solutions for such endeavors.

EMERGING PLAYERS

- Anduril
- Dive Technologies
- Notilo Plus
- Monterey Bay Aquarium Research Institute
- Woods Hole Oceanographic Institution
- DOF Subsea
- Ocean Floor Geophysics

1ST YEAR ON THE LIST

Autonomous Ships



The Yara Birkeland, the world's first crewless, zero-emissions, autonomous ship, set sail in November 2021 from Oslo, Norway.

KEY INSIGHT

Autonomous, AI-powered ships are moving from concepts to reality as two separate companies have completed successful maiden voyages of their respective autonomous technology. As legal frameworks are shifting to accommodate the authorized operation in international waters, the ships have also been equipped to adapt to navigational rules and regulations.

EXAMPLES

In November 2021, Yara, a Norwegian fertilizer producer, sent its highly anticipated Yara Birkeland on its maiden voyage, marking the world's first demonstration of an electric and autonomous containership. After traveling from Horten to Oslo, Yara plans to put the containership into operation, projecting to cut CO₂ by 1,000 tonnes and replace up to 40,000 trips by diesel-powered trucks a year. The ship relies on the Leclanché high-energy lithium-ion battery system, radar, lidar, an automatic identification system, and infrared cameras to operate. Despite the maiden voyage of the Yara Birkeland, the Japanese shipping company Mitsui O.S.K Lines claims to have operated the world's first sea trial of an uncrewed autonomous containership. In order to complete the voyage, the vessel took a number of variables into account including ship location, wind, tides, currents, ship handling elements, and navigational rules and regulations.

DISRUPTIVE IMPACT

Large autonomous ships could transform shipping by reducing environmental impacts, increasing efficiency, reducing costs, and reducing human error. Unmanned electric ships could result in cost savings along the supply chain and resiliency against potential labor shortages. When the notorious Ever Given blocked the Suez Canal in early 2021, environmental factors like heavy winds and a low water level contributed to the incident—elements that an AI-enabled navigation system could have potentially detected and compensated for. Interestingly enough, the very day before the Ever Given got stuck, its parent company, Evergreen, signed a deal with Samsung Heavy Industries for 20 new ships equipped with SVESSEL smart technology, including fuel-economizing features and intelligence systems. Autonomous ship technology could provide added protection from such incidents happening in the future.

EMERGING PLAYERS

- Yara International
- Mitsui O.S.K. Lines
- Samsung Heavy Industries
- Shone
- IBM
- Marine AI



Transportation

2ND YEAR ON THE LIST

Vehicular Biospheres



In 2015 Tesla began to manufacture cars with HEPA filters to improve the air quality within the car cabin.

KEY INSIGHT

Vehicle manufacturers are expanding their definition of safety to include protection from the elements whenever we are in or around a vehicle. As a result vehicles are becoming mobile biospheres that enable people to move through the world with increased safety from the outside world.

EXAMPLES

Tesla began installing and marketing HEPA air filters in its Model X cars beginning in 2015 but now includes them in its Model S and Model Y vehicles. These oversized air filters are part of a safety feature known as Bioweapon Defense Mode as they can filter particles as small as 0.3 micrometers, hence “military-grade biological contagions.”

In 2020 Volvo introduced Advanced Air Cleaner technology, which combines air filters and ionization with an interior air quality sensor. As a result, drivers can compare the air quality in their car versus outside.

DISRUPTIVE IMPACT

The pandemic has made people more sensitive to potential environmental hazards. While vehicles have always enabled people to create a semi-controlled environment on the move, the concept of what a vehicle can protect you against is expanding. Making personal safety cover more types of threats while also being mobile could change how we move from one safe space to another and how we view the time in between safe places.

EMERGING PLAYERS

- Tesla
- Volvo
- Philips
- Geely Healthy Car program

4TH YEAR ON THE LIST

Demand for Battery-Supported Transportation



Batteries need to come in all shapes and sizes to accommodate the increasing ways we want to get around.

KEY INSIGHT

Battery-powered transportation now extends beyond cars, trucks, and buses to motorized bicycles, hoverboards, skateboards, and scooters. These electric-powered forms of transportation are not going away and will be an increasing part of the transportation landscape going forward.

EXAMPLES

The increased transportation on non-gasoline powered vehicles will affect fossil fuel demand and the resulting energy distribution networks.

Volkswagen, the largest global automotive manufacturer, has announced plans to stop selling new fossil fuel powered vehicles in Europe by 2035. The majority of mainstream auto manufacturers have also set lofty objectives for electric cars with many first generation cars coming to market recently including vehicles from VW, BMW, Ford, and GM.

Battery-powered transportation is not limited to private travel either as Amazon has demonstrated keen interest through its strategic investment in Rivian. Rivian has reprioritized its business from consumer vehicles to commercial delivery vehicles to focus on delivering 100,000 electric Amazon delivery vehicles by 2024.

DISRUPTIVE IMPACT

Energy prices, reliable and safe batteries, and convenient, affordable recharging infrastructure will drive adoption of electric transportation. Utility providers will be pressured to improve grid resiliency as demand grows for domestic charging. Those first movers of charging infrastructure along travel routes will shift traffic patterns and create new networked economies—similar to how the interstate system created an economic boon for certain towns and hurt cities that were bypassed.

Incentives from federal and state governments to install charging stations along even less-traveled routes will drive adoption of electric vehicles over the coming years. As electric vehicles become more efficient and longer range, and drivers are assured that charging stations will be there when they need them, “range anxiety” is likely to lessen, removing one very significant psychological barrier from the embrace of electric vehicles.

EMERGING PLAYERS

- Ford
- GM
- VW
- Tesla
- BMW
- Rivian

EV Charger Roulette • Mid-future optimistic scenario

You're out of charge and stranded.
Spin the wheel to discover why!



1ST YEAR ON THE LIST

Alternative Fuel Supply



The Department of Energy tool helps people find charge points across the U.S.

KEY INSIGHT

Accelerating adoption of battery-powered transportation is leading to a rethink of how we provide the energy required to transport people and goods from A to B. How will our energy delivery systems need to adapt to a more battery-powered and less gasoline-powered transportation ecosystem?

EXAMPLES

Charging infrastructure outside the home has begun to standardize with the development of standardized plugs, units for measuring recharge rates, and interoperable charging points across multiple vehicle manufacturers. While “range anxiety” with electric cars still exists, the stress around the ability to charge along road trips and at what rate is beginning to decrease as fast chargers and standardized metrics become more readily available. Charging infrastructure along travel routes is not without its growing pains as it tries to rapidly scale up to the increasing demand from early adopters of the ever increasing number of plug-in electric vehicles. Tesla is in the process of opening up its charging network to other manufacturers but has been making very slow progress. It is piloting 10 supercharger stations in the Netherlands where non-Tesla vehicles can also use the charging infrastructure, but not all cars will be compatible due to short cables, stall layouts, and connector compatibility issues.

DISRUPTIVE IMPACT

Robust and reliable electrical grids become increasingly critical when transportation becomes dependent on the ability to charge batteries. In the U.S., the National Electric Highway Coalition includes 50 utilities and plans to address infrastructure gaps along major travel corridors by the end of 2023. By bringing utility companies into the effort, the coalition hopes to leverage better information on the existing grid capacity for deciding new station locations.

While fueling transportation with electrons from the electrical grid is of significant importance, other energy sources like hydrogen, natural gas, ethanol, and biodiesel will also need to be taken into consideration as we transition to energy delivery beyond mostly gasoline.

EMERGING PLAYERS

- Tesla
- ChargePoint
- Electrify America
- PlugShare
- U.S. Environmental Protection Agency
- National Electric Highway Coalition

EV Charging Levels

Access control

For more than 100 years, we've relied on gasoline to fuel our cars and trucks. At the pump, there are different choices: regular, mid-grade, premium, and diesel. Most cars can get by on regular gas, but some require premium, which has a higher octane rating and helps the engine perform better.

With electric vehicles, there are also an array of choices for recharging. Like other electronics, the levels (indicating the type of charge) depend on how much power a vehicle can accept, the power outlet it can use, and the amount of time it takes to fill up the battery.

There are three levels of charging, and the higher the level, the less time it takes to reach a full battery.

Level 1

These charging stations use a standard 120v outlet. The time to charge a vehicle's battery can take 60 or more hours.

Level 2

These are the most commonly available charging stations and are used most often for home charging. The time to reach a full battery is around 11 hours.

Level 3

These charging stations are known as rapid charging stations, and there are two standards: DC Fast Charging and Supercharging. Level 3 stations can fully charge a battery in under 30 minutes and most closely resemble the customer experience of gasoline-powered cars. Tesla's standard is Supercharging, and the company has the largest network of Level 3 charging stations in North America.



“It's no longer a matter of if, and it's no longer a matter of when, it's now the question is how fast? Because we know that the automakers have put the money into the retooling.”

— Jonathan Levy,
Chief commercial officer of EV
charging company EVgo

4TH YEAR ON THE LIST

Car OS



Technology companies are building operating systems for the cockpit that sidestep vehicle manufacturers.

KEY INSIGHT

Platforms are building operating systems for smart cockpits, initially using the phone as an interface.

EXAMPLES

The majority of new cars include the ability to control your phone through the built-in infotainment screens by either plugging it into a USB port or through a wireless adapter. Apple, Amazon, and Google are competing to expand their reach into the car by working with manufacturers to incorporate their software directly into driving interfaces. These systems are powered by a mobile phone's smart assistant and the specific apps consumers have installed on their phones. So, the experience can be updated, replaced, and refreshed at a much faster rate than when a new car is purchased.

DISRUPTIVE IMPACT

As driving assistants increase in ability, people will spend more and more time in their car without having to pay as much attention to driving. Consequently, the major platform players increasingly view the car ecosystem as prime real estate not only for customer attention but data collection. Volvo's new Polestar electric vehicles use Android Automotive OS, which was custom-built by Google to integrate its services in the infotainment experience. Simpler integrations include manufacturers like Volkswagen/Audi that utilize the built-in LTE internet connection to provide navigation with Google Maps instead of a proprietary offline maps file that is not regularly updated. By extending the reach of their smart assistants and software to the automotive environment, these companies are able to keep consumers within their ecosystem and collect ever increasing data with increasing specificity.

EMERGING PLAYERS

- Apple
- Google
- Volvo
- Volkswagen

6TH YEAR ON THE LIST

Transportation-as-a-Service Business Models



Transportation-as-a-service is not limited to bikes. Cars, jets, and even boats are adopting the business model.

KEY INSIGHT

The concept of transportation-as-a-service is gaining popularity as more companies use platform business models like ride-sharing to provide transportation without customers having to pay large upfront costs like when they buy a car or scooter.

EXAMPLES

Part of the appeal to consumers of transportation-as-a-service is that they do not need to make the large purchase to own a vehicle outright. Instead, customers can pay per use of a vehicle with all the costs of things like insurance and maintenance included.

The concept of transportation-as-a-service is extending beyond just pay per minute of electric bike rentals with rental car providers and even vehicle manufacturers piloting subscription-based systems for their vehicles. Hertz, Sixt, and Porsche offer some of the most celebrated subscription packages. The subscriptions aren't limited to cars either, with NetJets providing private airplanes and Carefree Boat Club providing access to boats.

DISRUPTIVE IMPACT

High upfront costs for purchase, maintenance, insurance, and rapid depreciation associated with traditional vehicle ownership will continue to dissuade people from purchasing vehicles when all they want to do is get from A to B. Subscription and per use models alleviate much of the downsides of traditional asset ownership for an increasing segment of the population who seek to limit commitment, while maximizing flexibility and cost-efficiency.

EMERGING PLAYERS

- Hertz
- Sixt
- Porsche
- NetJets
- Lyft

4TH YEAR ON THE LIST

Exponential Growth in Autonomous Driving Data



KEY INSIGHT

More data usually results in better algorithm performance, and the size of the data for training autonomous cars is accelerating at an exponential rate. There is an increase in real-world data from cars on the road, but synthetic data is being used to fill in the gaps.

Autonomous cars rely on algorithms trained on enormous real-world driving data, but that could be changing soon.

EXAMPLES

In 2018, Tesla reached its first billion miles driven with autopilot engaged after four years of testing. Then, Tesla added 2 billion more miles' worth of data, indicating the exponential rate of increase of real-world testing miles. The problem for the ecosystem is that Tesla's data isn't used by other car manufacturers.

New techniques are being developed and perfected in order to generate simulated testing miles, thus feeding the data-hungry algorithms without needing humans to drive physical cars around. Synthesizing data allows designers to train algorithms to better adapt and respond to situations that might be uncommon but have potentially catastrophic consequences. The fusion of synthetic and real world data is helping to accelerate the training of next-generation driver assistance and autonomous driving algorithms.

DISRUPTIVE IMPACT

The stakes are incredibly high for the group that creates the best driving assistance algorithms with the quality and size of the training dataset being an instrumental component to achieving the best possible product. Conventional wisdom suggests that the algorithm with access to the most data will have a competitive advantage over all other algorithms. The fusion of real-world data and synthesized data for training algorithms has tightened the race to generate as much training data as possible, as there are multiple paths to large training datasets.

EMERGING PLAYERS

- Waymo
- Tesla
- GM
- Ford
- Nvidia

5TH YEAR ON THE LIST

Regulating Autonomous Vehicle Testing



Regulating how autonomous vehicles are tested is still in progress.

KEY INSIGHT

The legislation around how, where, and under what conditions autonomous vehicles can be tested has yet to be set at a national level.

EXAMPLES

In June 2020, the U.S. National Highway Traffic Safety Administration created the AV TEST Initiative to provide the public with information about testing of autonomous vehicles. The objective is to raise public awareness to help the safe development, testing, integration, and education of autonomous vehicle technology in the U.S. The program includes information that states and companies self-report about the status of their various autonomous vehicles development initiatives. Arizona, California, Florida, and Nevada (along with some federal initiatives) lead in testing autonomous vehicles on public roads, with other states and countries catching up. Since 2012, at least 41 states and Washington, D.C., have considered legislation related to autonomous vehicles. More than 50 self-driving companies are testing their technologies in California.

DISRUPTIVE IMPACT

Creating learner's permits or driver's licenses for AI-enabled autos will help socialize the technology and establish expectations for experiences and protocols on the road. For autonomous vehicles to become safer, they must be tested in conditions similar to those where they will be deployed. Because of this dynamic, autonomous car services will likely arrive soonest in areas with existing testing sites. The fragmented regulatory environment, which will remain until federal laws and guidelines are imposed, will result in conditional and situational rules, such as how Cadillac centrally designates sections of road compatible with Super Cruise, its AI-enabled hands-free driving assistance product. If the regulatory framework around the use of autonomous vehicles on public roads remains fragmented, there could be a delay in the development of safe autonomous vehicles.

EMERGING PLAYERS

- Moral Machine
- Focus Group on AI for Autonomous and Assisted Driving
- U.S. National Highway Traffic Safety Administration
- National Conference of State Legislators
- International Telecommunication Union

4TH YEAR ON THE LIST

Analog Fallbacks



How do you get out of your car if it's frozen shut and you have no door handle?

KEY INSIGHT

Historically mechanical systems are increasingly built in an electric-only format without a fallback strategy if they fail. Electrical systems are usually more fragile than their analog counterparts, meaning failures are likely to become harder to assess, repair, and recover from.

EXAMPLES

Many car locks today depend on electricity and become inoperable when the car battery dies. Tesla's Model 3 has a mechanical system for the front doors but not the rear doors. Such vulnerabilities can cause life-threatening scenarios: A failed car battery locked the doors of an Ohio man's Cadillac and trapped him in the car for 13 hours, and, in another case, a Texas man and his dog died in his Corvette as a result of the same problem. Both vehicles had manual door release mechanisms as a fallback for when electrics failed, but neither person could find the release. To make matters more tragic, one of the victims had the vehicle owner's manual yet was still unable to activate the manual release mechanism. These problems will be exacerbated when cars no longer come with physical user manuals or when firmware updates change a car so drastically that the original physical manual is no longer accurate.

DISRUPTIVE IMPACT

As vehicles become more automated, manufacturers must design for the appropriate level of redundancy for a population of people with limited understanding of how the underlying systems work. Communication of these designs increases in importance as digital systems enable firmware updates that can drastically change what and how a car does what a user wants it to do.

EMERGING PLAYERS

- Cadillac
- Tesla
- Range Rover

Unashamedly, this is a high-end product. It's an awesome machine. It's a true luxury electric car...We're able to charge nearly 300 miles of range in just 20 minutes. No one else is even close to that.

— Peter Rawlinson, CEO, Lucid Motors

2ND YEAR ON THE LIST

China's Global Auto Ambitions



NextEV recently debuted its Nio EP9 hypercar.

KEY INSIGHT

China produces more cars than any other country in the world. While their manufacturing volume leads globally, Chinese brands have not yet reached saturation in overseas markets. China's ambitions to dominate the global car industry are buoyed by its manufacturing sector, work in AI, and global competitiveness.

EXAMPLES

Chinese domestic brands are starting to make headway with a global audience. During the 2022 Super Bowl, a little-known Volvo spinoff called Polestar took a dig at Tesla, bragging that it had no plans to conquer Mars, and highlighting “no Dieselgate” as a key feature. Polestar is a joint venture between Zhejiang Geeling Holding Group, which also owns Volvo. NextEV launched its Nio EP9 hypercar, and the company has plans to bring mainstream sports-car models into production this year. Chinese companies including HAAH and Chery, which make more affordable passenger cars, hope to break into the U.S. market.

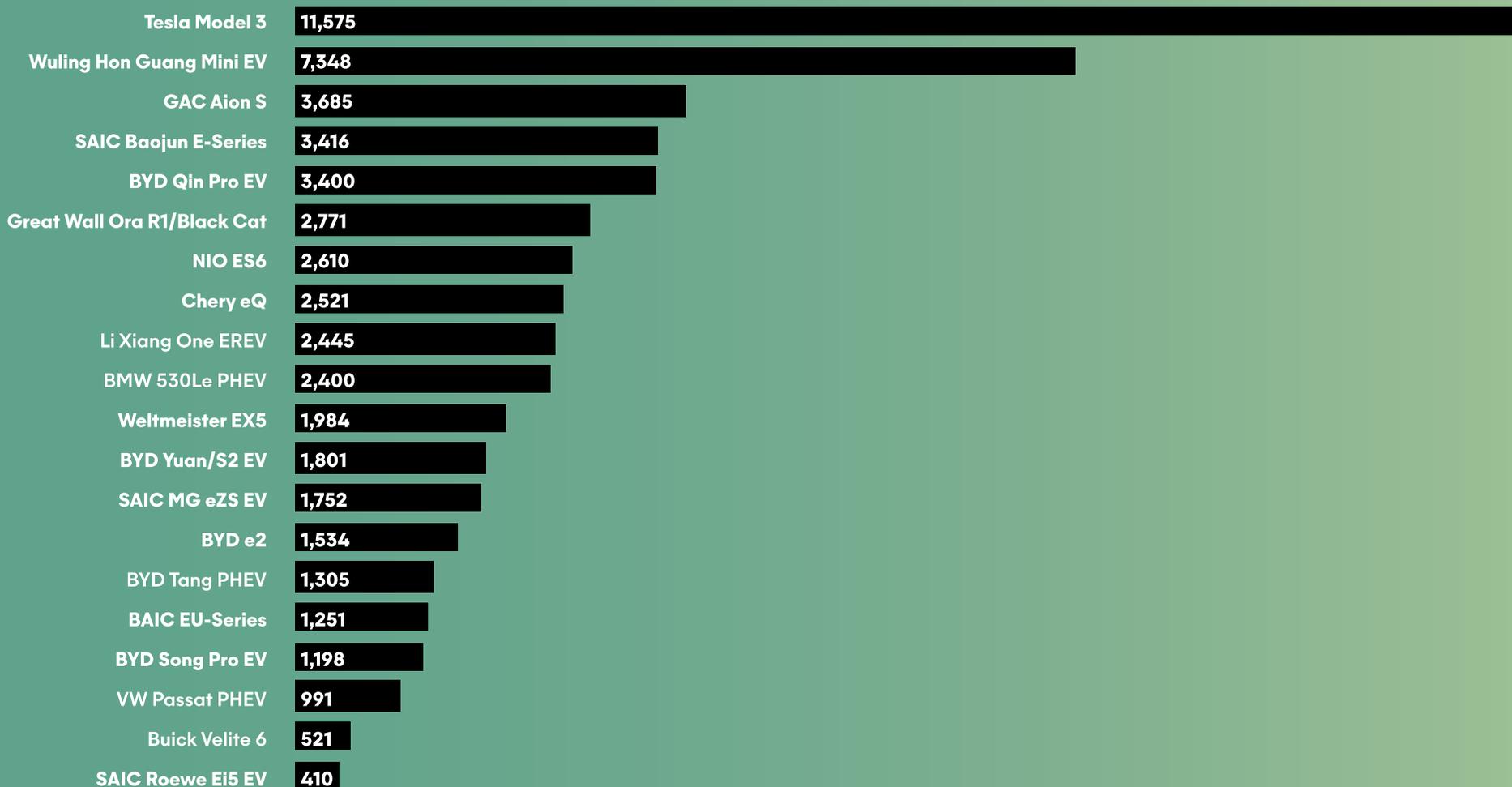
DISRUPTIVE IMPACT

China is leading the charge for the future ecosystem of mobility with manufacturing, electric vehicles, apps, communications systems, AI, and data at its center. The advances in manufacturing technology from Tesla's Giga Shanghai factory are already starting to form the basis for higher efficiency production methods for other domestic Chinese manufacturers, like advanced casting machines developed by LK Group for Tesla. Baidu's Apollo is another leading example of a ready-for-export technology where a collaboration of international and domestic companies are developing an open-source self-driving system.

EMERGING PLAYERS

- China Association of Automobile Manufacturers
- Zhejiang Geeling Holding Group
- Li Auto
- Xpeng Motors
- Tesla
- Apollo Committee
- LK Group

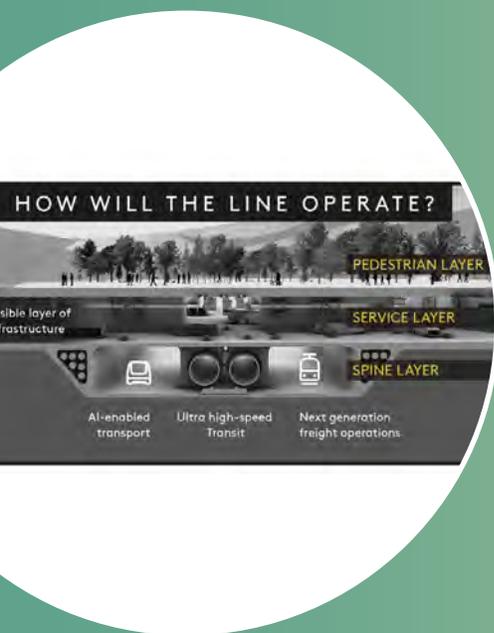
China Electric Vehicle Sales — July 2020



Bold: Fully electric
 Chart: CleanTechnica • Source: EV Volumes

2ND YEAR ON THE LIST

New Cityscape Designs



The Line is a linear city proposed in Saudi Arabia.

KEY INSIGHT

The importance placed on roads is decreasing in urban planning with autonomous vehicles, sustainability, and technology leading the charge for how urban spaces are being designed.

EXAMPLES

Saudi Arabia is developing a futuristic new approach to urban planning and city design through its ambitious NEOM project. Its centerpiece is a 106-mile-long belt of connected communities which is being called The Line. The linear city will stretch from the Red Sea to the mountains in northwest Saudi Arabia. The goal is to be a city of 1 million people using clean energy where daily needs like schools and shops will be within a 5 minute walk and no journey will be longer than 20 minutes. The Line plans to achieve its transportation design objectives by using a multilevel spine that will include local and high-speed transit, a service layer, and a pedestrian layer. Construction has already begun with earth being moved and creations for tunnels taking shape for a city that hopes to have its first residents in 2024.

DISRUPTIVE IMPACT

With climate change accelerating, more and more is being asked of urban planning with greater considerations for sustainability, flexibility, and future adaptability. These large-scale, interconnected urban planning projects are an approach toward redesigning how we live and how we consume resources. We may have little choice, as sea levels rise and extreme weather events force us indoors or even underground.

EMERGING PLAYERS

- Bjarke Ingels Group
- Arquitectonica
- Rockwell Group
- NEOM CEO Nadhmi Al-Nasr

2ND YEAR ON THE LIST

Decarbonizing Flight



ZeroAvia is developing hydrogen-electric powertrains for air travel.

KEY INSIGHT

Airplane travel accounts for 2.5% of global carbon dioxide emissions, and efforts are underway to decarbonize travel.

EXAMPLES

NASA has been working on using electric planes to help solve aviation carbon pollution for the past decade through the development of the X-57 Maxwell, an all electric plane. The experimental two-seater plane will have a range of 100 miles. The technology NASA is working on will hopefully help scale electric planes from 20 person planes to 100 person commuter planes.

While the energy density of batteries is improving, other options include hydrogen as a zero-emission fuel source. ZeroAvia is developing hydrogen-electric powertrains to replace traditional fossil fuel engines. Their projected timeline is 2024 for commercial planes of 10–20 seats going up to 50+ seats by 2026 and 200+ seats by 2040.

DISRUPTIVE IMPACT

Aviation contributes 3% of the world's total carbon emissions. When flights stopped during the COVID-19 pandemic, there were noticeable changes to air pollution. As air travel returns to pre-pandemic levels over the next few years, there will be increased calls to reduce emissions. Hydrogen-powered planes, while still under development, could be a viable alternative.

EMERGING PLAYERS

- ZeroAvia
- Airbus
- NASA

4TH YEAR ON THE LIST

Foreign Infrastructure Investment

KEY INSIGHT

The governments and companies that lead international infrastructure projects have powerful influence on setting regional, global and geopolitical standards.

EXAMPLES

China's multibillion-dollar Belt and Road Initiative began in 2013, focusing primarily on investment in infrastructure, education, construction, rail, highway, auto, and electrical grids. The program has provided the motivation for new trade links and diplomatic ties through financing and development expertise.

The European Union has announced a competing initiative of \$340 billion called Global Gateway. The European alternative will focus on financing to support digitization, clean energy, transport, health, education, and research. The group aims to increase investments promoting democratic values and high standards, good governance and transparency, equal partnerships, green and clean, secure infrastructures and that catalyze private sector investment.

DISRUPTIVE IMPACT

The balance of geopolitics may be significantly impacted by large infrastructure initiatives that have the ability to create new trade relationships with mutual self-interest and aligned approaches to tackling large problems.

Critics of the Belt and Road Initiative worry that Chinese financing will create unsustainable debt especially among the developing nations that are most in need of these large infrastructure projects.

EMERGING PLAYERS

- European Commission
- European Investment Bank
- Asian Infrastructure Investment Bank
- New Development Bank
- National Development and Reform Commission



The Council on Foreign Relations has been tracking Belt and Road Initiative participants and the impact on geopolitical relations.

Image credit: Council on Foreign Relations.



In the distant future, people may outlaw driving cars because it's too dangerous. You can't have a person driving a two-ton death machine.

— Elon Musk, CEO, Tesla



How these trends impact your company



STRATEGY

Multiple forces are coming together to disrupt and challenge company operations, including growing consumer demand for transparency and sustainability, continued supply chain pressures, worker shortages, and expectations for rapid turnaround times. Companies can address some of these challenges by evaluating areas of their operations where inefficiency is greatest, and streamlining activities, leveraging technological solutions where possible.



INNOVATION

Robotics, drones, supply chain technologies, and evolving transportation are coming together to transform operations for businesses of all industries in the near future. Companies and their organizations should begin to evaluate their value chain, and identify areas that are manually intensive, dangerous, or easily repeatable. These tasks could be good candidates for enhancement through technology, and create renewed opportunities for human workers to work on enhancing and transforming organizations.



R & D

Several technologies in the fields of robotics and drones are still relatively nascent, such as self-assembling robots, drone swarms, and microelectromechanical systems (smart dust). These technologies exist today but require real-world trials and tests to reach their maximum potential. Businesses, likewise, are best suited to identify unique use cases for these tech solutions based on their greatest needs or barriers. Safety, security, health, and connection are four key driving forces behind the development of these capabilities, showcasing their potential to positively impact both company and worker experiences and consumer outcomes in the near future.



GROWTH

We anticipate sustained growth in all of these areas, particularly in robotics and drones. Current adoption of these technologies has been on a consistent rise over several years, and decreasing cost and increasing efficiency of these solutions will only serve to drive further growth. While companies have a huge opportunity to benefit from these improved solutions, governments likewise could leverage these systems to support U.S. agriculture, battle climate change, improve countrywide infrastructure, and unlock new potential in existing supply chain systems.

Key Questions

We recommend using this report to support your strategic foresight activity in the coming year. Every executive team should begin by asking these questions:

1

- ▶ What parts of our business model and value chain are experiencing the greatest inefficiency?

- ▶ How are we addressing the rising consumer demand for greater sustainability?

2

- ▶ What new types of data might we unlock by implementing more technological solutions into our processes?

- ▶ How might we use that data to reach new markets or enhance our offerings?

3

- ▶ What entirely new ways of doing business might be possible in the next few years as these technologies improve?

- ▶ How might we get our products to customers differently in five years?

Selected Sources

<https://arxiv.org/abs/2104.00800>

<https://phys.org/news/2022-01-starfish-shaped-soft-robot-self-heals-broken.html>

<https://www.nature.com/articles/s41586-021-04029-6>

<https://www.science.org/doi/10.1126/sciadv.abf6312>

<https://doi.org/10.3390/s22010325>

<https://www.ncsl.org/research/transportation/autonomous-vehicles-self-driving-vehicles-enacted-legislation.aspx>

<https://doi.org/10.1038/s41467-021-21007-8>

<https://arstechnica.com/cars/2021/11/us-charging-infrastructure-is-outpacing-forecasts-study-finds/>

<https://www.weforum.org/agenda/2021/08/hydrogen-aviation-zero-emissions/>

<https://www.iea.org/reports/global-ev-outlook-2021/policies-to-promote-electric-vehicle-deployment>

<https://www.frontiersin.org/article/10.3389/fbioe.2021.720217>

<https://itif.org/publications/2022/01/20/launching-advanced-manufacturing-institute-space>

<https://venturebeat.com/2022/02/01/supply-chain-startup-loadsmart-raises-200m-to-automate-logistics-processes/>

<https://www.fooddive.com/news/sustainability-label-claims-are-influencing-more-consumers-cargill-survey/618432/>

<https://www.chemengonline.com/toray-announces-plans-for-block-chain-supported-traceability-platform/>

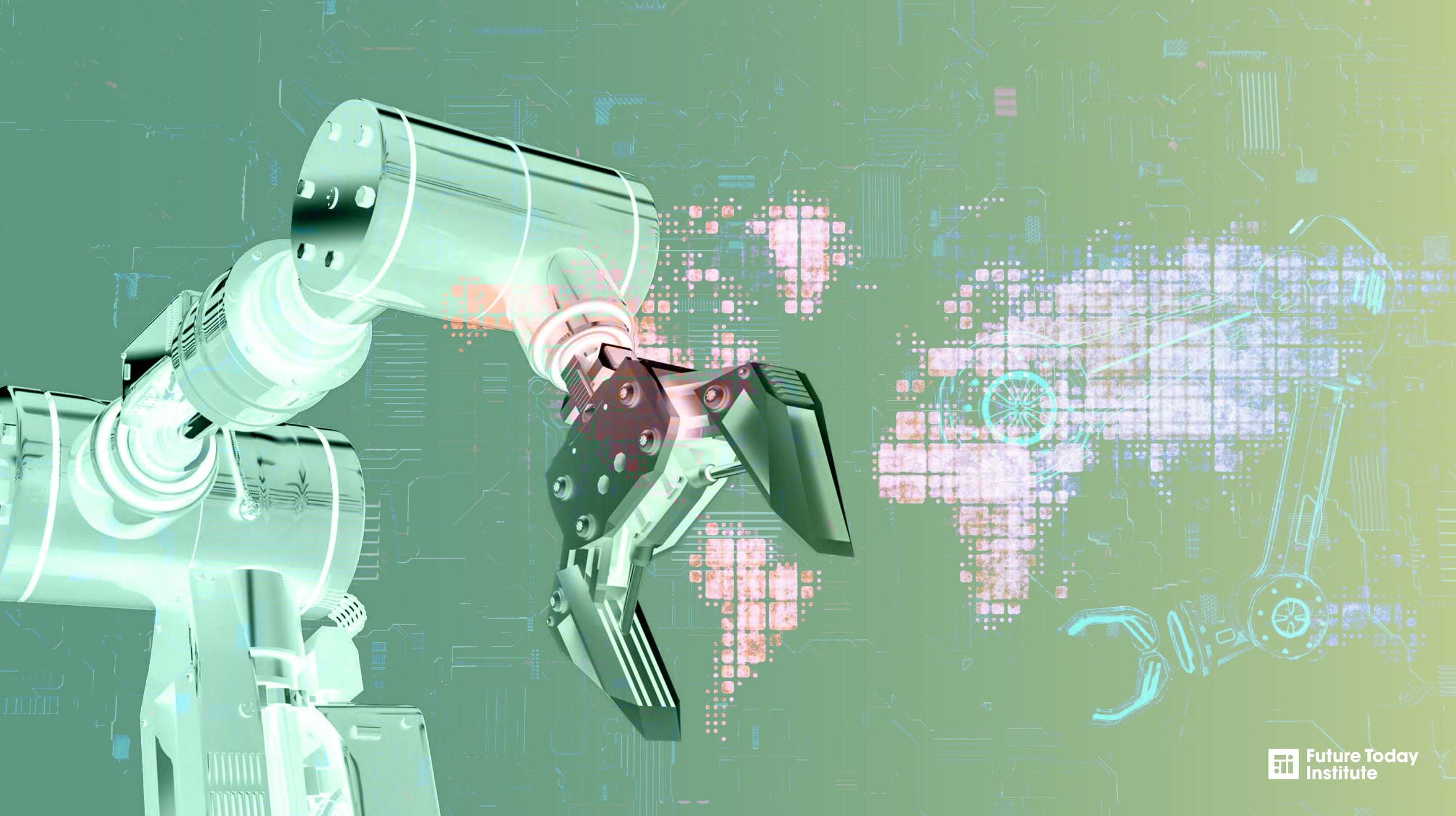
<https://www.thedefensepost.com/2022/01/11/raytheon-drone-swarm-darpa/>

<https://www.science.org/content/article/fleet-sailboat-drones-could-monitor-climate-change-s-effect-oceans>

<https://www.iihs.org/news/detail/iihs-creates-safeguard-ratings-for-partial-automation>

<https://www.axios.com/sidewalk-robots-legal-rights-pedestrians-821614dd-c7ed-4356-ac95-ac4a9e-3c7b45.html>

<https://www.businessinsider.com/experts-say-an-autonomous-delivery-robot-next-big-thing-2022-2>



Decentralization & Blockchain

Blockchain, cryptocurrency, DeFi, decentralization, and NFT trends influencing business, government and society.

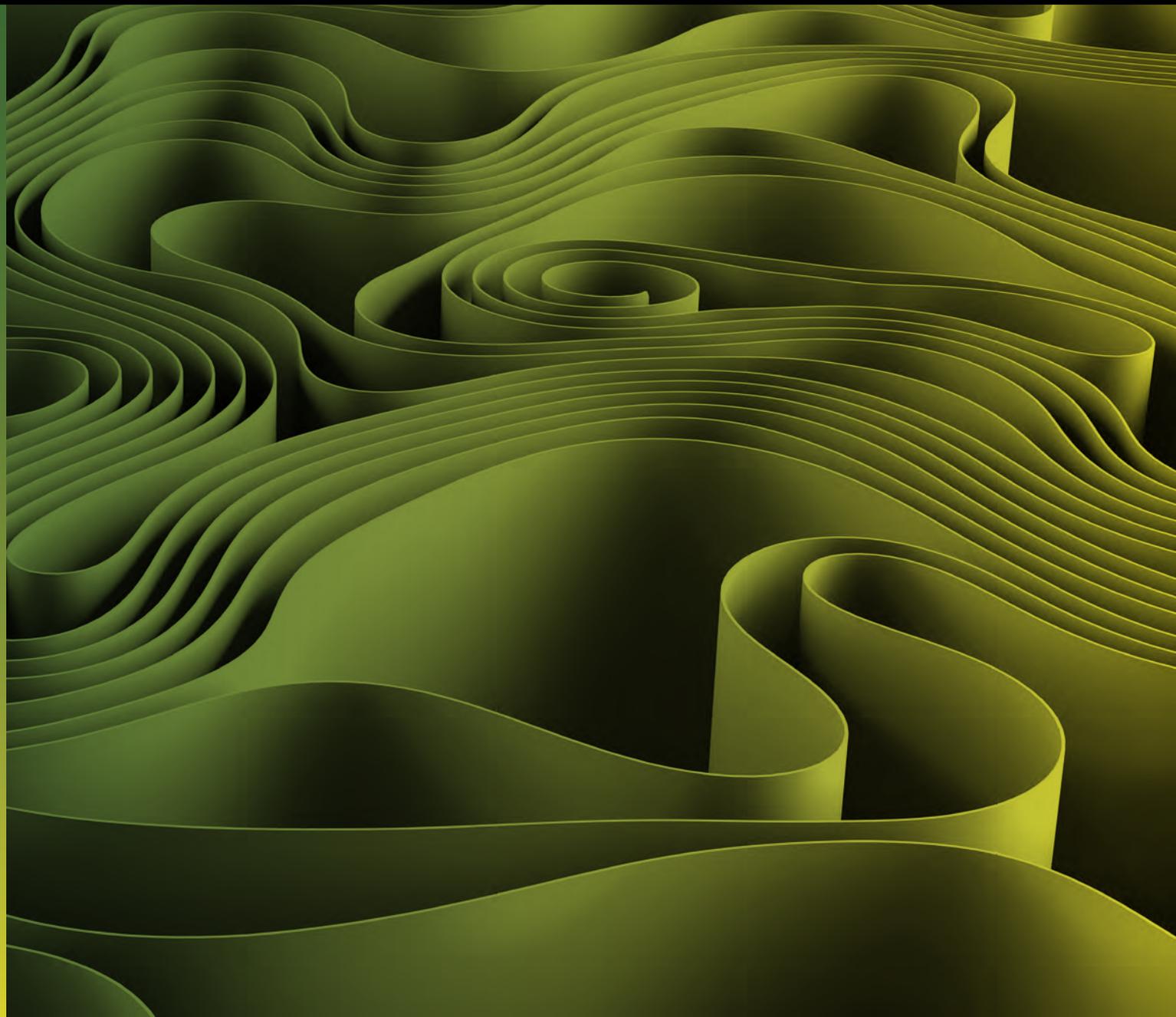


Table of Contents

461 Key Insights	488 Decentralized Finance (DeFi)
462 Currency	489 Better Digital Wallets
463 Stablecoins	490 Learn to Earn Models
464 Hometown Coins	491 DEXes and AMMs
465 CBDCs	492 On-chain Surveillance
466 Payments and Settlements	493 Staking
467 Social and Digital Payments	494 Smart Oracles
468 Conditional Money	496 Non Fungible Tokens (NFTs)
469 Earned Wage Access	497 Non Fungible Tokens
470 Banking	498 Smart Royalties
471 Open Banking	499 Monetizing Memes
472 Alternative Credit Scoring	500 Proof of Everything
473 Web 3.0	501 Knock-On Trends
475 Provenance and Authentication	502 Crypto Mining Fuels Green Energy
478 Scenario: Regulation Z Prime	503 Community Dashboards
479 Token Economics	505 Application
480 Digital Autonomous Organizations (DAOs)	506 Key Questions
481 Fractional Ownership	507 Selected Sources
483 Tools to Manage Digital Identity and Assets	
484 Fan Ownership Models	
485 Scenario: Consumption Quota	
486 Distributed Computing Earning Models	
487 Self-Finding Digital Infrastructure	



The material presented in this report is intended for informational purposes only and should not be considered investment advice, or a recommendation to buy, sell, or hold any particular cryptocurrency, digital asset, or security.



Key Insights

- * In the near future, money will be programmable—and more things could become money-like, with quantifiable, liquid, and fungible qualities.
- * The financial ecosystem is undergoing a transformation as blockchain technology and open-source protocols introduce alternatives to existing regulatory and capital controls.
- * Due to the surge of interest in non fungible tokens (NFTs), developers are making digital wallets easier to use by wider groups of consumers.
- * Ethereum has become the dominant blockchain now underpinning thousands of decentralized applications and is the primary contracting platform for NFTs and decentralized finance (DeFi). Ether, which underpins the Ethereum network, is emerging as the dominant collateral in DeFi.
- * China will push for the broader use of its digital currency, the e-CNY, within and outside of the country.
- * Visa had a monopoly on payments at the Olympics for 36 years, and in 2022 China's e-CNY was the preferred payment inside the Olympics bubble.
- * Decentralized databases, powered by blockchain, could enable secure and transparent community dashboards on everything from water quality to city budgets, improving public trust and civic engagement.
- * The bimonthly paycheck may soon be a thing of the past. Earned wage access (EWA) lets employees receive part of their earned wages in between paychecks.
- * Banks and insurance companies are using artificial intelligence, telematics, and big data to automate credit risk modeling and update the way credit scores are calculated.
- * Blockchain-based applications are being used to track the origins of content online, and permanently store original assets, improving the ability of consumers and businesses to authenticate information. This is a powerful tool for combatting censorship and misinformation.
- * Decentralized autonomous organizations (DAOs) will continue to grow this year. As of March 2022, DAOs have more than \$10 billion of assets under management.
- * Crypto tokens and blockchain networks are being developed so that fans can own portions of their favorite brands.
- * Cryptocurrency developers have created software to decentralize the stocks and securities exchange process, allowing individuals to trade directly with one another without relying on a centralized third party to determine prices and settle the trades.



Currency

2ND YEAR ON THE LIST

Stablecoins



Tether remains one of the most popular stablecoins, despite controversy surrounding the company.

KEY INSIGHT

While most people are familiar with Bitcoin, another category of cryptocurrency—stablecoins—is the most widely used. Stablecoins are “pegged” to another asset or a basket of underlying assets. This creates price stability, allowing people to transact with digital facsimiles of commodities and currencies.

EXAMPLES

By far the most popular stablecoins are Tether and USDC, which are both pegged to the U.S. dollar. While Tether is the most widely used stablecoin, it is also surrounded by controversy as it has faced lawsuits and failing audits related to its cash reserves. Tether’s value proposition is that it is “tethered” to the value of a dollar, and for every Tether in circulation, Tether Ltd., its parent company, has a dollar in its cash reserves. Interestingly, the controversy has not hampered investor interest or global adoption. In November 2020, Visa announced a partnership with Circle to develop a credit card that uses USDC. The regulatory landscape for this innovation is still evolving. In late 2020, U.S. Rep. Rashida Tlaib (D.-Mich.) introduced the STABLE Act, which would require companies issuing stablecoins to obtain a banking license. In 2021, Treasury Secretary Janet Yellen and Federal Reserve Chair Jerome Powell both called for stablecoin regulation. SEC Chair Gary Gensler has been particularly vocal about his criticism of stablecoins.

DISRUPTIVE IMPACT

Stablecoins, specifically those pegged to the dollar, give people and businesses around the world access to trade in a universal means of exchange without going through traditional financial hurdles. This has had positive impacts for people who want to store their savings in a stable asset instead of a local currency suffering from inflation. It’s been a useful tool for faster, more affordable remittances. This also raises regulatory concerns for circumstances where stablecoins are used to evade currency controls and sanctions.

EMERGING PLAYERS

- Binance
- Circle
- Coinbase
- Meta (formerly Facebook)
- Gemini
- Tether
- Visa

1ST YEAR ON THE LIST

Hometown Coins



Communities and cities are beginning to explore how creating their own cryptocurrency can unlock new opportunities and benefits.

KEY INSIGHT

Community currencies, also known as scrips, have allowed cities, towns, and even neighborhoods to experiment with their own monetary policies for centuries. Now, with the advent of blockchain, there is a resurgence of local currencies and exploration of their potential.

EXAMPLES

Miami is the first city in the United States with crypto on its balance sheet thanks to MiamiCoin, a project that establishes crypto treasury funds for a city and allows anyone to contribute. The MiamiCoin treasury raised \$4.5 million in 40 days, and the Miami City Council voted to use the funds to mitigate climate change, serve underprivileged communities, and provide incentives for tech entrepreneurs. A similar effort is underway in New York City. In Kenya, the Sarafu network has almost 48,000 registered users engaging with a local virtual currency.

DISRUPTIVE IMPACT

Backed by smart contracts and accessed on smartphones, local currencies can lead to more resilient and diverse economies. International development aid was over \$150 billion in 2020; distributing it through local currency networks instead of food donations or grants could reduce waste and corruption. Projects like MiamiCoin demonstrate how municipalities can raise funds without hiking taxes or going into debt. Hometown coins can support local initiatives like backing small businesses, reinvesting in city infrastructure, and attracting talent.

EMERGING PLAYERS

- CityCoins
- Miami
- Grassroots Economics

3RD YEAR ON THE LIST

CBDCs



The People's Bank of China launched a pilot app that provides access to its digital currency, the E-CNY.

Image credit: Costfoto/Future Publishing via Getty Images.

KEY INSIGHT

While digital payment rails have exploded in popularity in recent years, the majority of innovation has occurred in the private sector. Central bank backed digital currencies—CBDCs for short—are blockchain-backed tokens issued and managed by central banks. More and more, governments are researching issuing digital currencies of their own in an effort to modernize the monetary system.

EXAMPLES

CBDCs could update some of the most antiquated areas of global finance. China is the undisputed leader in CBDCs, successfully executing multiple large-scale pilots including at the 2022 Olympics. The rest of the world is following suit, with countries like Nigeria releasing frameworks and white papers for their own projects. The U.S. Federal Reserve has partnered with MIT on Project Hamilton, an in-depth research study in this area, but has yet to commit to issuing a U.S. CBDC. Not everyone is a fan. Controversial whistleblower Edward Snowden has called CBDCs “cryptofascist currencies,” since many implementations of this technology would give states greater surveillance and control of individual citizens and their transactions.

DISRUPTIVE IMPACT

CBDCs give citizens a public alternative to digital payment infrastructure, in theory allowing for transactions and financial services without exorbitant fees. They could streamline global flows of currencies and foreign exchange markets. The World Economic Forum’s policymaker toolkit for helping central banks investigate CBDCs calls them a potential tool for improved safety and resilience in payments systems; competitiveness of payments systems; better data transmission and reporting to central banks; and financial inclusion.” CBDCs could also expedite the distribution of emergency relief funds after natural disasters or health pandemics. In the case of humanitarian aid, digital currencies are easier to track and monitor. For that reason, critics say that CBDCs also present privacy and surveillance concerns. China is spearheading efforts to establish global standards for CBDCs in order to make them interoperable and compatible.

EMERGING PLAYERS

- People’s Bank of China
- Central Bank of Nigeria
- Central banks
- MIT Digital Currency Institute
- World Economic Forum



00

01

02

03

04

05

06

07

08

09

10

11

12

13

Decentralization & Blockchain

Payments & Settlements

13TH YEAR ON THE LIST

Social and Digital Payments



Apple's new Tap to Pay feature will make it easy for businesses and individuals to accept payment and exchange funds with a tap of devices.

KEY INSIGHT

Tech companies are leveraging APIs and digital infrastructure to provide seamless, interconnected financial services. Financial institutions, payment providers, and consumer-facing companies are integrating with tech platforms and e-commerce to acquire more customers and fend off competition.

EXAMPLES

For well over a decade, companies such as Venmo and PayPal, which now have hundreds of millions of users, have worked to bring social payments to consumers all over the world. Consumer-to-consumer (C2C) purchases are increasingly enhanced through services like Shopify, which save a buyer's payment details and make it simple to repeatedly purchase products online without entering any new information. A new announcement by Apple in February 2022 could move C2C and consumer-to-business (C2B) one step closer together. The tech giant launched Tap to Pay on iPhone—a capability that will enable individuals to exchange funds simply by bringing their smartphones closer together. Apple believes this new app will lead to businesses accepting contactless payments as well, without the need for additional equipment.

DISRUPTIVE IMPACT

This area is rapidly evolving as payment capabilities migrate from apps to devices. Visa is working with auto companies such as GM and Honda to launch connected car payment capabilities including Visa Token Service, CyberSource Payment Management, Token ID, and Visa Direct. Car-based payments could streamline transactions such as paying for curbside groceries or meals, gasoline or electric charges, or parking.

EMERGING PLAYERS

- Affirm
- Ant Group
- Apple
- Amazon
- Baidu
- Green Dot
- Google
- PayPal
- Shopify
- Venmo
- Visa
- WhatsApp
- Zelle/Bank of America

1ST YEAR ON THE LIST

Conditional Money



With Bolsa Família, as cash transfers are digitized, recipients' behavior can be more closely monitored and controlled.

KEY INSIGHT

International aid often comes with conditions for the recipient's behavior such as how the funds are used, and so do the funds parents give to children. Now, apps and payment services are making it possible to automate such conditions, allowing for monitoring and spending controls of sub-accounts. In the near future, money itself may enforce controls for how it can or cannot be spent.

EXAMPLES

Greenlight is a startup with more than 4 million users that offers a debit card with parental controls and a mobile app. Parents can block certain stores and impose spending limits and rewards based on behavior. In the world of humanitarian aid and international development, conditional cash transfer (CCT) programs have been widely successful, distributing cash payments as individuals meet specific milestones in areas such as education and health. Bolsa Família is a longstanding successful CCT program. As cash transfers are digitized, recipients' behavior can be more closely monitored and controlled.

DISRUPTIVE IMPACT

As these two signals converge, it's likely we'll see a world where money behaves differently depending on the wallet it's stored. In individual exchanges, the sender could ensure that the recipient spends the money on the intended items—for example, a parent sending money to a child at college to purchase textbooks. We could also see businesses begin to place conditions on expenditure as well, however—in one possible use case, homeowners insurance companies could place restrictions on claim payments to ensure that the money actually goes toward replacing the damaged or lost items.

EMERGING PLAYERS

- Gates Foundation
- Greenlight
- Bolsa Família

1ST YEAR ON THE LIST

Earned Wage Access



Solutions like Instant Financial's allow employees to immediately access a portion of their pay after every shift.

KEY INSIGHT

The bimonthly paycheck may soon be a thing of the past. Earned wage access (EWA) lets employees receive part of their earned wages in between paychecks. EWA differs from a payday loan since it is usually offered through an employer or connected to a payroll processor at lower fees or completely free of charge.

EXAMPLES

Gig work companies like Uber and Lyft pioneered EWA by letting their drivers access their earnings daily for a fee. In 2019, Square was awarded a patent for instant payroll deposits. About a dozen startups including Clair, Green Dot, Instant Financial, and Earnin are actively developing products in this space, promoting financial inclusion and targeting gig workers, hourly earners, freelancers, and contractors—a growing segment of the labor force.

DISRUPTIVE IMPACT

Immediate access to payroll will directly lead to more employee surveillance and monitoring. Amazon recently came under fire for its draconian “time off task” productivity metric, and yet as more employees ask for EWA benefits, employers will likely put in place additional measures to track their work.

EMERGING PLAYERS

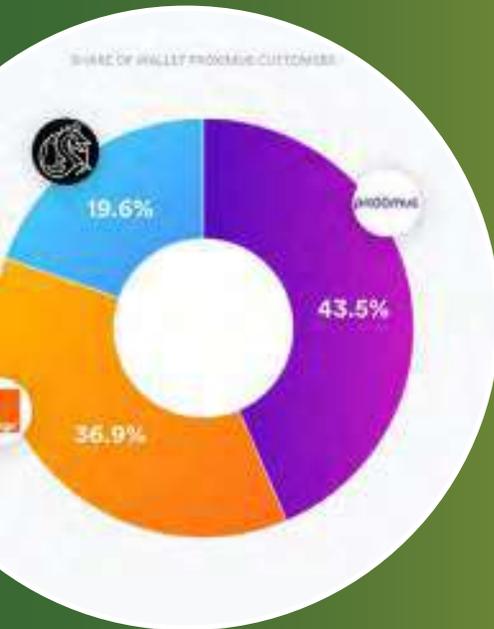
- Clair
- DailyPay
- Earnin
- Green Dot
- Instant Financial
- Payactiv
- Square



Banking

1ST YEAR ON THE LIST

Open Banking



Part of Cake's integration offers insights to business customers by leveraging millions of anonymized transactions. Utilizing open banking APIs, Cake can bring together unique data and insights that would otherwise be unobtainable or prohibitively expensive to secure.

KEY INSIGHT

Open banking enables secure interoperability between third-party organizations and financial institutions, allowing for the creation of tools, products, and platforms that pull together data from various financial institutions into one location.

EXAMPLES

Efforts to implement open banking began in earnest around 2019, when countries including Australia, Canada, and the U.K. implemented practices and directives that allowed banks to make consumer data available upon request, most often via APIs. The CMA9, the nine largest banks in the U.K. per the Competition and Markets Authority, have been mandated to implement open banking in the region, and announced in early 2022 that the number of open banking users in the U.K. had recently surpassed the 5 million user milestone. Since the inception of this practice, the United States has seen a multitude of startups emerge that aim to pull together financial information for the convenience of users.

DISRUPTIVE IMPACT

Open banking enables the creation of banking-as-a-service offerings today. Many of these help users make better use of their financial information, and offer analysis that assists with budgeting. Several apps aim to help users trim the fat from their budget, by marrying their financial data with usage data from other apps to suggest which subscriptions to cancel. In the short term, the main benefit is convenience and optimization. In the longer term, however, this technology could enable seamless financial transactions in virtual or highly connected interfaces, in a way that feels invisible and automatic for the user.

EMERGING PLAYERS

- AIB Group UK
- Bank of Ireland
- Barclays Bank
- Cake
- FIS
- Fiserv
- HSBC Group
- JHA
- Lloyds Banking Group
- Mint
- Nationwide Building Society
- NatWest Group
- Northern Bank
- Personal Capital
- Plaid
- Santander U.K.
- Simplifi

9TH YEAR ON THE LIST

Alternative Credit Scoring



Companies are leveraging artificial intelligence and new data sources to evaluate credit.

KEY INSIGHT

Banks and insurance companies are using artificial intelligence, telematics, and big data to automate credit risk modeling and update the way credit scores are calculated.

EXAMPLES

Today, credit reporting agencies including FICO and Experian offer alternative credit scoring products that use payment data from monthly utility bills and deposit account information. Startups are getting into the space, too; Spin Analytics reads data first and then runs models as needed. It's just one example of the AI-powered automated credit risk modeling services that are now being studied by central banks and tested at commercial banks including BBVA and Crédit Agricole.

Personal insurers are seeking new methods of assessing risk as states increasingly ban the use of credit scores in modeling and price setting. California, Hawaii, Massachusetts, and Michigan already banned the use of credit scores for setting auto insurance rates, and the state of Washington added a ban in 2021. Companies are responding—Root Insurance uses the accelerometer in mobile phones to assess customers' driving and issue a quote.

DISRUPTIVE IMPACT

Most alternative credit scoring mechanisms today focus on other financial indicators, such as income or monthly expenditures. However, more sophisticated AI or automated methods that could emerge as a result of improved data or connected devices could begin to draw from behavioral or more personal characteristics. In many historical cases, use of AI in credit modeling has increased bias against marginalized groups, typically due to misinterpretation or application of demographic data. Automated processes that are based on behavior and not demographics could result in more equitable outcomes.

EMERGING PLAYERS

- Experian
- FICO
- Kabbage
- Root Insurance
- VantageScore
- Upstart
- TomoCredit
- Zest AI



00

01

02

03

04

05

06

07

08

09

10

11

12

13

Decentralization & Blockchain

Web 3.0

Web 3.0

Web 3.0 Explained

In the 1990s, most of the web was “read only.” The average consumer could seek out and read information using a browser like Netscape or Internet Explorer. The goal of this early commercial internet, or Web 1.0, was to present content and products to consumers, much like a catalog.

The second iteration of the web, or Web 2.0, gave rise to read, write, and publish capabilities. Blogger and LiveJournal kicked off the platform era, where any consumer could upload content (including videos and audio), sell items, and build communities. Social media sites soon followed, and Facebook, Twitter, and YouTube became dominant players. This era consolidated market share among just a few big tech giants, which now wield tremendous power.

Conceptually, Web 3.0 is intended as a return to the decentralized iteration of the internet in which individual users have more autonomy and control of their privacy and data through the use of blockchain technology to enable new types of transactions and authentication of ownership. Think of Web 3.0 as the next step on a longer continuum, which enables broader computer-to-computer interactions over the internet and easier human-to-machine experiences.

Key Web 3.0 Developments

Web 3.0’s foundation in blockchain will enable individuals to build out their own connected spaces and assets in ways that previously weren’t possible. Advanced techniques in data mining, natural language processing, and text analytics will make gathering and understanding unstructured data much easier. Machines will collaborate directly with one another and, eventually, teach one another.

Companies like Blockstack and Cosmos are building networking products that will unlock a new generation of applications and services. Reddit co-founder Alexis Ohanian’s VC firm, Seven Seven Six, announced in early 2021 a partnership with Polygon, a technology solutions company that specializes in Ethereum-compatible protocols, to develop new Web 3.0 solutions. Other first movers, such as Reddit and Twitter, are actively investing in new Web 3.0 applications in order to be prepared for the evolution.

Web 3.0 Applications

The metaverse, a buzzy term since Meta’s late 2021 announcement, will be highly dependent on the Web 3.0 infrastructure. Tokenization, proof of ownership, seamless financial exchange, and provenance authentication—all primarily blockchain-based capabilities—will drive the development of the metaverse. Likewise, the advancement of smart cities, smart contracts, and emerging Internet of Things capabilities will not be possible without Web 3.0 software and infrastructure. Just as cloud computing revolutionized how businesses manage and store information, blockchain and distributed computing will enable a new wave of innovation for information technology and databases, as well as for how consumers and businesses interact and engage.



Web 3.0 enables people, organizations, and systems around the globe to be seamlessly interconnected while acting independently, allowing for more equitable access to asset ownership and investment.

4TH YEAR ON THE LIST

Provenance and Authentication



Content provenance applications are being used to track the origin of information and validate its authenticity and accuracy.

KEY INSIGHT

Blockchain-based applications are being used to track the origins of content online and permanently store original assets, improving the ability of consumers and businesses to authenticate information. This is a powerful tool for combating censorship and misinformation.

EXAMPLES

The Coalition for Content Provenance and Authenticity (C2PA) released version 1.0 of its technical specification in early 2022. This protocol provides guidance to content creators on how they can generate tamper-evident media by selectively disclosing certain pieces of information about their content. Many companies are coming together under the C2PA including Arm, Microsoft, and Twitter, in order to combat misinformation online and create easy ways for consumers to detect whether content has been tampered with and trace it to its original source. The C2PA protocol leverages a technique called hard binding, in which an asset and its details and descriptors, as well as its source of origins, are cryptographically bound together. Any alteration to the asset would result in a mismatch that changes the underlying mathematical algorithm, making it possible to detect if the content has been tampered. The News Provenance Project traces the origins of journalistic content

and detects doctored or manipulated images and videos.

Permanent archival is another process made possible by blockchain technology—this open, decentralized, permanent archive of data occurs through protocols such as Arweave. Arweave describes itself as a collectively owned hard drive that allows users and developers to store data forever.

DISRUPTIVE IMPACT

This type of technology can be used for convenience—never reaching a broken link on the web again—but it can also prevent censorship or suppression. Governments and large corporations routinely delete, alter, or censor online information, but blockchain lets us create a shared permanent ledger from which nothing can be deleted. By adding original content or an index to the blockchain, journalists and media companies can make their content permanent, verifiable, and traceable.

After censorship by WeChat, Chinese activist Yue Xin at Peking University used the Ethereum blockchain in 2018 to publish a letter that detailed a pattern of abuse and intimidation from school administrators. This method was effective in archiving it; however, transaction costs of Ethereum or other cryptocurrencies could make the cost of archiving large bodies of information prohibitively high. In contrast, LikeCoin is a decen-

Provenance and Authentication



Content provenance applications are being used to track the origin of online content such as news and files and archive them accurately.

tralized publishing infrastructure built for content archival. In mid-2021, when Radio Television Hong Kong began deleting content that covered protests in 2019, users quickly backed up episodes from RTHK. Those episodes were then archived through LikeCoin, which only stores metadata but backs up its content on the InterPlanetary File System, or IPFS—a peer-to-peer file sharing service—to publish and preserve otherwise censored content, such as news articles and Wikipedia pages.

EMERGING PLAYERS

- Coalition for Content Provenance and Authenticity
- Content Authenticity Initiative
- The News Provenance Project
- Adobe
- Arm
- BBC
- Intel
- Microsoft
- Truepic
- Associated Press
- Internet Archive
- The New York Times
- InterPlanetary File System

There's a critical need to address widespread deception in online content—now supercharged by advances in AI and graphics and diffused rapidly via the internet. Our imperative as researchers and technologists is to create and refine technical and sociotechnical approaches to this grand challenge of our time. We're excited about methods for certifying the origin and provenance of online content. It's an honor to work alongside Adobe, BBC, and other C2PA members to take this critical work to the next step.

—Eric Horvitz, chief scientific officer and Project Origin executive sponsor, Microsoft

Regulation Z Prime

In the early 2020s, fintech companies and large banks bought up providers of “buy now, pay later” or BNPL services—and the mechanism became an embedded finance component of online shopping checkout systems. Soon, BNPL became so commonplace that banks now use it as the primary means for extending credit, effectively getting rid of personal lines of credit and loans.

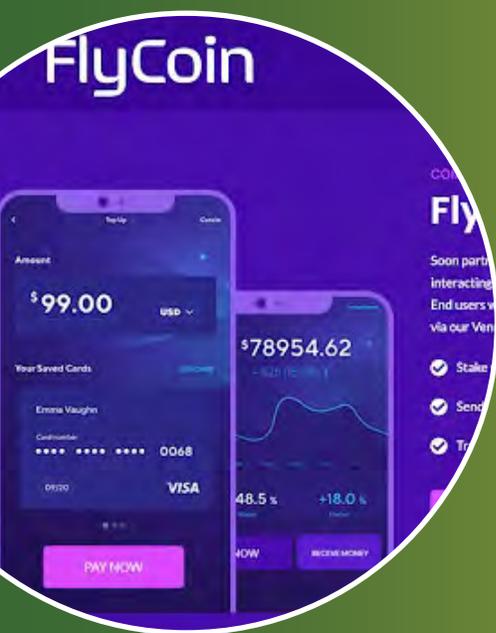
Banks and other financial providers see BNPL as a way to capture revenue with high interest rates that they can apply to unsuspecting consumers who want immediate gratification: Think: that new VR headset right now.

With rampant growth and no regulation, BNPL is pervasive, much like the incessant pop-up ads of the early 2000s. Banks offer BNPL to people who can't afford or understand debt because their creditworthiness models accept anyone who makes any purchase. Much like the mortgage crisis of 2008, lenders wrongly believe they can confiscate the goods purchased as collateral. Because of this zombie collateral, the loans are tranced and redistributed at higher ratings, recreating conditions for the great credit crunch of 2035.



1ST YEAR ON THE LIST

Token Economics



FlyCoin touts its position as the world's first crypto frequent flyer program. Airlines like regional provider Ravn Alaska are rewarding with FLY coins, which can be used to pay for flights.

KEY INSIGHT

Token-based business models are developed when a company or entity issues a token that represents usage, utility, value, or a combination of the three. Token economics encompasses everything from incentive mechanisms, supply schedule, distribution, and platform governance. This is gradually revolutionizing how companies finance their operations and do business.

EXAMPLES

Every cryptocurrency has a specific monetary policy. For example, Bitcoin has a fixed supply of 21 million and a gradually decreasing issuance rate, set at 6.25 bitcoins per block (as of this writing). Ethereum has no fixed supply and a variable issuance rate that depends on network demand. The economic model of these projects helps users estimate price and use cases. Token projects design their monetary policy based on what they are optimizing for. For example, Binance, the world's largest crypto exchange, issued Binance Coin (BNB) in 2017. People who hold BNB can use it for discounted trade rates, exclusive products, and other services. Binance regularly "burns" or destroys coins to regulate the circulating supply.

DISRUPTIVE IMPACT

The internet has enabled a wide range of new business models such as free-mium, shared-economy, aggregator, direct-to-consumer, and so on. Blockchain and cryptocurrencies are creating even newer business models such as smart royalties, fan ownership, and compounding yield.

Companies are also experimenting with the economics of loyalty. American Express is one such company, which partnered with Boxed in 2018 to experiment with a customized blockchain-based loyalty program. Singapore Airlines likewise tested out a digital miles wallet program for customers. One recent entrant is FlyCoin, which airlines use to reward customers with FLY coins, which can be redeemed to purchase future flights. As loyalty programs evolve, we expect to see more blockchain loyalty platforms emerge that enable customers with these types of rewards to apply across a wide variety of their favorite services.

EMERGING PLAYERS

- Binance
- Ethereum
- FlyCoin

1ST YEAR ON THE LIST

Decentralized Autonomous Organizations (DAOs)



Constitution DAO consisted of an effort by a group of people to purchase a rare copy of the U.S. Constitution—a move that would have allowed the group to do whatever they wanted with the document once in their possession.

KEY INSIGHT

A DAO is an organizational model where processes are automated, principles are codified on-chain, and mechanisms exist for members to generate value. Collectively, DAOs have over \$10 billion of assets under management. DAOs exist across various industries including finance, art, media, and law.

EXAMPLES

The first DAO began with Ethereum in 2016 and lasted only a few months before it was hacked due to an exploited vulnerability in the source code. While the original DAO was short-lived, many other DAOs have proliferated in the years since. The earliest DAOs were treasury management systems, designed to allow token holders to determine the direction of a project, new features, engineering road map, and business strategy. Newer DAOs include freelancer guilds where remote workers can pool their talents to find clients, investment DAOs where members can comanage a portfolio of assets, and media DAOs that have unique incentives to encourage engagement and monetize content. Uniswap, a popular decentralized exchange, formed a DAO when it distributed governance tokens (UNI) to every address that had used the platform before Sept. 1, 2020. Friends With Benefits is a social DAO where token holders can buy season passes for access to exclusive events and content.

DISRUPTIVE IMPACT

Think of DAOs as co-ops for the web. DAOs facilitate the collective ownership and creation of value. While still in their infancy, DAOs offer promising approaches to classic coordination problems such as managing resources and aligning incentives.

EMERGING PLAYERS

- Uniswap
- MakerDAO
- Compound
- Friends With Benefits

2ND YEAR ON THE LIST

Fractional Ownership



In August 2021, over 400 people collectively purchased CryptoPunk 2066 for 1,144.5 ETH, which at the time was worth over \$3.5 million.

KEY INSIGHT

Fractional ownership is reemerging as blockchain and digital platforms unlock new ways to purchase and own assets. This method for unrelated parties to divide costs and risks in order to collectively own or invest in an asset is most commonly seen in real estate. It's now appearing in fine art, stocks, as well as other industries thanks to the proliferation of business models enabled by smart contracts.

EXAMPLES

Fundrise is a real estate fintech company based in Washington, D.C., that organized the first crowdfunded real estate development project in the U.S. Otis and Masterworks are two companies that offer fractional ownership for works of art. Schwab and Robinhood recently launched the feature to purchase fractional shares of stocks on their trading platforms. In August 2021, more than 400 people collectively purchased CryptoPunk 2066 for 1,144.5 ETH, which at the time was worth over \$3.5 million. CityDAO is a decentralized community raising funds to buy a parcel of land in Wyoming.

DISRUPTIVE IMPACT

Most of these companies have a stated mission to democratize investing. While the sharing economy prioritized access over ownership, people are still looking for ways to create and preserve wealth. In theory, more people participating in value creation would lead to more equitable distributions of wealth in the long term. On the other hand, as more people participate in speculative markets, there could be an increase in speculative bubbles and economic instability.

EMERGING PLAYERS

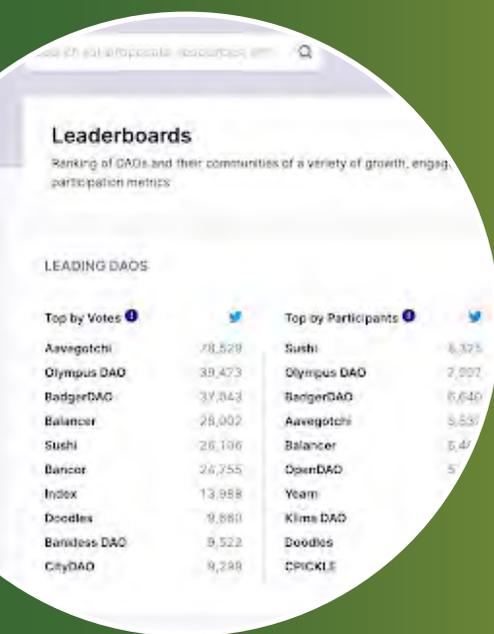
- CityDAO
- Fractional
- Fundrise
- Masterworks
- Otis
- PartyDAO
- Robinhood
- Roofstock
- Schwab

“
NFTs represent a first step in the securitization of digital assets. They turn digital data into speculative financial instruments. That shift has enormous implications because computers are in everything, and that makes anything a digital asset—your bank records, your Fitbit data, rings of your smart doorbell, a sentiment analysis of your work email, you name it.
”

— Ian Bogost, writing in *The Atlantic*

1ST YEAR ON THE LIST

Tools to Manage Digital Identity and Assets



Boardroom shows a ranking of DAOs and their growth, allowing users to easily see DAO activity as it happens.

KEY INSIGHT

Decentralized applications and autonomous communities give individuals more control but also require more engagement and understanding to realize their full benefits. A new generation of coordination tools will help individuals manage their assets and identities across applications. Just as Slack replaced email, which replaced paper memos, these tools will change how people work, play, and interact online.

EXAMPLES

Boardroom and Tally are dashboards that show upcoming governance votes across many DAOs and decentralized projects. Tally also has a leaderboard that ranks the most active voters in the network. Snapshot allows decentralized communities to put up proposals for a vote while tools like Gnosis Safe lets people lock funds in an account that requires multiple signatures. VC firm a16z has open-sourced its process for delegating voting power to more active community members. In this way, the firm is creating a road map for how individuals can have a stake in a community, and keep the community active and engaged while personally taking a less active role.

DISRUPTIVE IMPACT

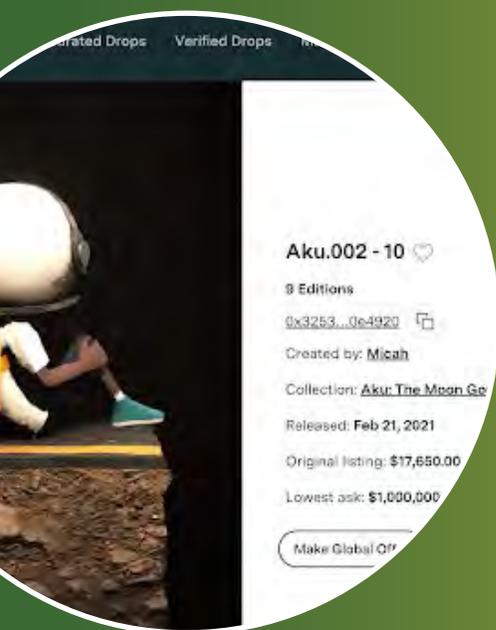
In the near future, people will expect much more control and modularity across devices, platforms, and applications. If Twitter is considering banning a certain politician or celebrity, users will expect to have a vote in that decision. This generation of coordination tools is providing a dramatic improvement in user experience and driving engagement within decentralized projects. It's possible that these tools will be adopted in corporate governance cases or use cases that require a great degree of transparency such as labeling offensive content or misinformation. It is less likely that these applications will find their way to civic systems such as political elections because they rely on completely public votes, and oftentimes votes are weighted by the value in a given wallet.

EMERGING PLAYERS

- Snapshot
- Gnosis
- Boardroom
- Tally
- a16z

1ST YEAR ON THE LIST

Fan Ownership Models



High prices like that listed for an Aku NFT on the Nifty Gateway site enable access to unique content that will roll out over time to a limited ownership base.

KEY INSIGHT

Sports, movies, and music all derive value based in part on the size and strength of their fanbase. Crypto tokens and blockchain networks allow fans to own their favorite brands.

EXAMPLES

Krause Haus is a collective of basketball enthusiasts raising funds to buy and manage an NBA team. Aku is a young astronaut created by former baseball player Micah Johnson and the first NFT (non fungible token) optioned to become a major feature film. Aku's story is released in chapters and distributed to fans who hold the chapter 1 NFT. Early Aku community members will be rewarded in perpetuity across various vertices. European soccer clubs have raised millions of euros through fan tokens. It hasn't all been smooth sailing in the realm of blockchain-backed fan ownership. Point guard Spencer Dinwiddie attempted to tokenize his \$34 million contract with the Nets and was met with legal hurdles and opposition from the NBA.

DISRUPTIVE IMPACT

On the surface, fan tokens might seem like a gimmick rewards program for front-row seats, exclusive merch, and unique experiences. If done well, fan tokens can be much more powerful than that—directing important decisions for a brand or creator and earning part of the profits should the brand increase in value overtime. The challenge for many of these projects will be finding regulatory clarity on their token models and avoiding scrutiny from agencies like the SEC.

EMERGING PLAYERS

- Aku
- Krause Haus
- Galaxy
- Rally

Consumption Quota

China and the US are neck and neck for the world's largest GDP in 2025. GDP is a global vanity metric that countries use to assert dominance over one another. The world's largest GDP is a coveted spot to have in terms of negotiating global trade agreements and geopolitical policies.

Gross Domestic Product optimizes for consumption. It's a calculation that combines public and private spending and investment. In a world where everything is disposable, producible, purchasable, citizens now also have a civic duty to spend.

During World War II, many governments rationed certain products like automobiles, gasoline, silk, shoes and food like meat, dairy, coffee and sugar. In the future, governments like the US and China might do the opposite - setting consumption quotas on citizens to ensure their rank in the global economy.

Universal Basic Income and other guaranteed income programs are ubiquitous. Citizens are punished for not spending fast enough since their digital wallets are publicly visible and tracked.



4TH YEAR ON THE LIST

Distributed Computing Earning Models



KEY INSIGHT

Large computer problems can be broken down into smaller portions and solved using processing power of multiple standard computers, rather than with centralized supercomputers. Distributed computing technology lets people donate idle processor time on their personal laptops, cell-phones, and other digital devices to support causes or solve socially relevant problems.

It is estimated that the Folding@Home program on COVID-19 research was leveraging over 470 petaflops of computing power.

Source: Stanford University School of Medicine

EXAMPLES

In 2020, Folding@Home grew to reach 2.4 exaflops—more than the top 500 supercomputers in the world put together—and became one of the fastest computing systems due to increased interest during the COVID-19 pandemic. Folding@Home lets consumers donate idle processing power to fuel disease research via their computers, PlayStation 3s, and some Sony smartphones.

In February 2022, the MilkyWay@Home initiative, which aims to create an accurate three-dimensional model of the Milky Way galaxy, announced that the distributed computing power of its network enabled the measurement of the mass and shape of a dwarf galaxy. Another astro-obsessed distributed computing system, Einstein@Home, uses the computing power it gathers from volunteers to search for weak signals from spinning neutron stars, in order to ultimately make the first direct detections of gravitational-wave emissions from spinning neutron stars.

DISRUPTIVE IMPACT

Distributed computing systems harness the idle processing power of computers all over the world and are being used to solve tremendous world problems. These distributed systems drive down prices for developers and make it possible for organizations to accomplish greater volumes of research in a much faster time frame. Expect to see more applications in the coming years that allow individuals to contribute to such altruistic projects by donating their time, as well as a greater number of applications that allow device owners to sell their idle processing power, providing them with a new source of income.

EMERGING PLAYERS

- Berkeley Open Infrastructure for Network Computing
- Einstein@Home
- LHC@Home
- MilkyWay@Home
- MLC@Home
- Rosetta@Home
- Folding@Home
- Stardust@Home
- DreamLab
- Electric Sheep
- Golem Network
- The Great Internet Mersenne Prime Search
- TheSkyNet

2ND YEAR ON THE LIST

Self-Finding Digital Infrastructure



KEY INSIGHT

Much of the internet relies on FOSS, free open-source software.

Free open-source software helps source and fund individual distributors that wish to contribute to the development and maintenance of public blockchains like Bitcoin.

EXAMPLES

Open-source software has often suffered from the “tragedy of the commons” problem in that many people are willing to use a free resource but less willing to maintain it. Open-source development is difficult, and the primary contributors to a project often suffer from burnout and poor compensation. To remedy this, some corporations “sponsor” developers so that they can dedicate their time to development. New mechanisms are surfacing to enable sustainable digital infrastructure.

Gitcoin is a marketplace of bounties for open-source developers who want to contribute to projects and earn income for their work. It caters primarily to the Ethereum blockchain community. Since 2017, Gitcoin has facilitated almost \$40 million of funding to open-source software projects. Other crypto projects such as Zcash earmark a portion of each “block reward” (the amount of new coins that enters circulation with each new block) to go toward community development.

DISRUPTIVE IMPACT

Many cryptocurrency and blockchain projects depend on open-source development. This industry is also pioneering new funding models that could result in more sustainable and more robust digital infrastructure.

EMERGING PLAYERS

- Bitcoin
- Ethereum
- Gitcoin
- Zcash



Decentralized Finance (DeFi)

1ST YEAR ON THE LIST

Better Digital Wallets



Trust Wallet can also be used to access decentralized apps, many of which can leverage or seamlessly interact with the DeFi vehicles (coins) in a user's wallet.

KEY INSIGHT

Digital wallets securely store payment information on mobile devices, browsers, and even wearables. Wallets made for Web 3.0 will let you do more than just buy a cup of coffee. They can offer greater levels of autonomy by giving users full custody and control over their digital assets or the ability to sign smart contracts.

EXAMPLES

In December 2020, FinCEN was considering implementing heightened rules for “self-hosted wallets,” referring to wallets that are not provided by a financial institution or crypto service, residing instead on a user’s computer or offline. Self-hosted wallets are similar to a physical billfold tucked into your back pocket—as you have money stored there, no one can prevent you from using it. Financial service providers typically ask for personal information when setting up an account in order to adhere to KYC/AML requirements. Metamask is one of the most popular wallets for accessing applications built on Ethereum and related blockchains, reaching over 10 million monthly active users as of August 2021. Its users can sign smart contracts directly from their web browser. Other Web 3.0 wallets specialize in specific protocols or use cases, such as letting users lock funds to provide liquidity to the network and earn interest or participate in governance decisions.

DISRUPTIVE IMPACT

It is challenging for companies to toe the line between convenience and security, compliance, and user privacy. Web 3.0 wallets offer users more choices for how to store digital assets; however, they also require more tech-savvy to navigate.

Web 3.0 wallets emphasize personal responsibility and self-sovereignty. They tend to save more information on the local device as opposed to a centralized server in the cloud. For this reason, Web 3.0 wallets will likely accelerate and improve the experience around 2FA, password managers, and other security tools. User expectations and behaviors will shift as the experience and design of these applications improve. The value proposition of many of these products is that there’s no Big Brother watching you; the trade-off is that there’s no one to call if you forget your password.

EMERGING PLAYERS

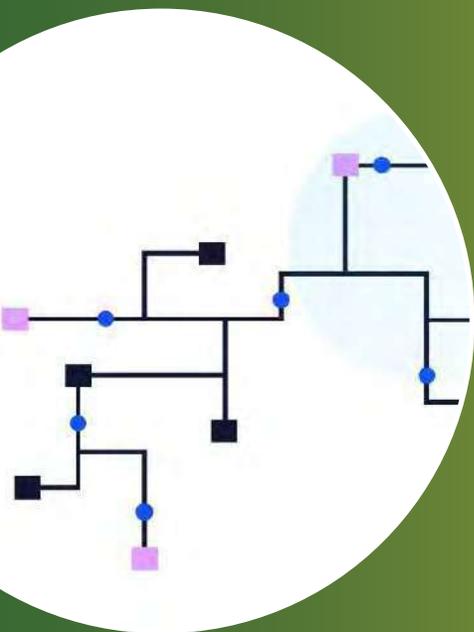
- MetaMask
- Trust Wallet
- Decred

1ST YEAR ON THE LIST

Learn to Earn Models

KEY INSIGHT

Individuals are earning digital currencies by learning how these currencies work. Decentralized platforms benefit from new participants in the network. Micro-payments enable small payouts and blockchain infrastructure allows for a database of verifiable transactions. All of these elements reflect a clear trend of financial incentives around education and product adoption.



Coinbase users can take brief lessons and complete quizzes to earn crypto tokens.

EXAMPLES

1729.com is a newsletter that pays you instead of the other way around. Each edition generally comes with a task that subscribers can complete, the best submissions earning a few hundred dollars. Rabbothole.gg takes it one step further; the website is a series of quests, challenges, and projects that anyone can participate in and earn crypto upon completion. Coinbase, one of the largest cryptocurrency exchanges, has an educational platform where users can earn \$5 to \$10 in crypto by watching a series of videos and completing short quizzes.

DISRUPTIVE IMPACT

Verifying digital credentials, whether for education, job recruiting, or social networking, has long been a challenge primarily because there is no standard for who issues the credential and who recognizes its validity. This has led to a cottage industry of learning experience platforms like Lynda.com (acquired by LinkedIn for \$1.5 billion) and learning management systems. For a nascent industry like blockchain, individuals are demonstrating their skill sets simply by showing their wallet address, and the industry is still small enough to coalesce around a standard. It's possible that as the blockchain industry grows, its native standard for credentialing will displace the existing status quo.

EMERGING PLAYERS

- Rabbothole.gg
- 1729
- Gitcoin
- Credly
- Degreed
- LinkedIn

2ND YEAR ON THE LIST

DEXes and AMMs



Kyber's Swap interface enables users to quickly exchange coins at the best possible price by giving users access to multiple DEXs at the same time.

KEY INSIGHT

Cryptocurrency developers have created software to decentralize the stocks and securities exchange process, allowing individuals to trade directly with one another without relying on a centralized third party to determine prices and settle the trades.

EXAMPLES

Centralized exchanges such as the New York Stock Exchange or Nasdaq facilitate trades of stocks and securities by maintaining a fair, consistent, and transparent process for publishing prices and orders. By decentralizing this process, cryptocurrency developers' software enables investors to trade with each other without a centralized third party. This decentralized exchange (DEX) is usually accomplished through automated market maker (AMM) algorithms.

In traditional finance, market makers provide liquidity in a market by holding both buy and sell positions. In cryptocurrencies and fully electronic markets, assets can be priced based on algorithms instead of the order books used in traditional trading venues such as stock markets. DEXes and AMMs often go hand in hand.

DISRUPTIVE IMPACT

Pricing algorithms and automated markets are not new, as most of the early applications were in prediction markets and sports betting. Blockchains and digital currencies have led to explosive growth: In 2018 and 2019, the yearly trading volume for decentralized exchanges was around \$2.5 billion. In the first half of 2020, decentralized exchange trading volume had already exceeded \$6 billion. In 2021, monthly trading volume for DEXes was over \$100 billion every single month with over 200 active decentralized exchange protocols.

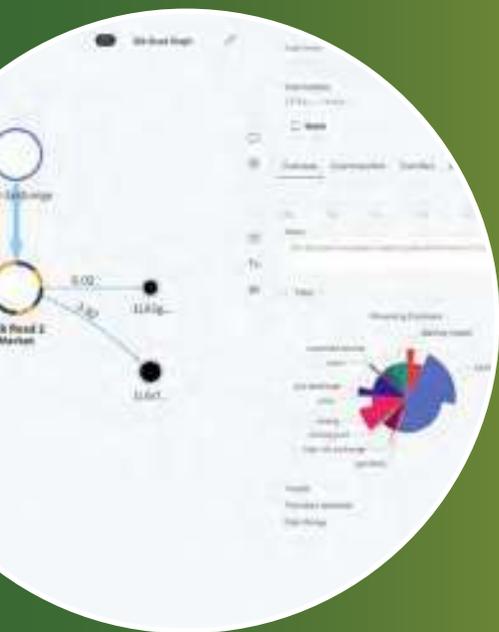
Both of these trends—decentralized exchanges and automated market makers—are part of a larger wave of decentralized finance or DeFi. As more aspects of the global financial system are digitized, there will be a greater demand for modern, impartial, secure systems to settle trades and transactions. DEXes and AMMs are still in the very early days, so bugs, bubbles, and user experience hurdles are to be expected. Still, the underlying innovation in finance is undeniable.

EMERGING PLAYERS

- Uniswap
- Curve
- Compound
- 0x
- Kyber
- dYdX

1ST YEAR ON THE LIST

On-chain Surveillance



KEY INSIGHT

Since many digital currencies require a public ledger of all transactions in order to operate, all activity in the network is visible to the public, offering zero financial privacy. As the total market cap for cryptocurrencies nears \$3 trillion, the incentives to monitor on-chain activity grow.

Participants of Chainalysis' Reactor product can investigate cryptocurrency transactions, to make connections to real-world organizations and individuals.

EXAMPLES

Everyone found out what Mark Cuban was investing in when he promoted his favorite NFT (non fungible token) in January 2021. Because of the nature of Ethereum and Bitcoin, nearly everyone can see the full history of transactions and wallet balance once they discover the wallet address. Context is a company that lets you follow people's on-chain activity to determine which NFTs to invest in next.

DISRUPTIVE IMPACT

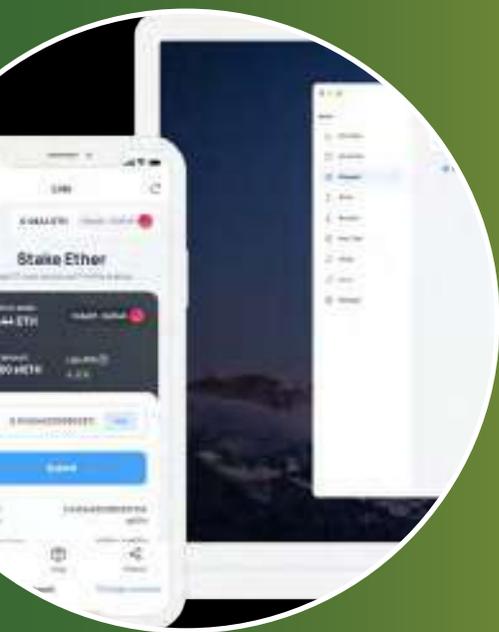
It took BuzzFeed reporters 10 minutes to figure out Joe Biden's Venmo account, and die-hard "Bachelor" fans follow their favorite celebs' Venmo accounts to predict who will receive a rose. Financial surveillance is nothing new; sadly, it seems to be accelerating thanks to digital currencies and fintech. Ironically, a technology born from cypherpunks and privacy advocates seems to be ushering in an unprecedented era of surveillance.

EMERGING PLAYERS

- Chainalysis
- Context

1ST YEAR ON THE LIST

Staking



KEY INSIGHT

Staking allows you to earn rewards based on the cryptocurrencies you hold. Ethereum, the second-largest digital currency after Bitcoin, popularized what's known as the proof-of-stake algorithm for producing blocks.

Investors can use services like Ledger to stake a variety of cryptocurrencies and earn rewards. The process can be as simple as traditionally swapping coins on a decentralized exchange.

EXAMPLES

The staking mechanism requires users to lock up a given amount of their holdings in order to receive a larger amount after a given period. Staking is beneficial because it adds liquidity and stability to the network.

Staking is the backbone of many DeFi (decentralized finance) models such as yield farming, self-paying loans, and community-owned liquidity. Yield farming refers to the investment strategy of locking in funds to a protocol in order to earn rewards, and reinvesting those rewards in the same or a different protocol to earn more, to chase the highest yield. As of November 2021, the total value of currencies staked or “locked” was \$112 billion, almost 10 times what it was the year before.

DISRUPTIVE IMPACT

Staking schemes might raise eyebrows for their astronomical APY rates (upward of 8,000%), but the premise is not really different from many interest-based models that make up the current financial services industry.

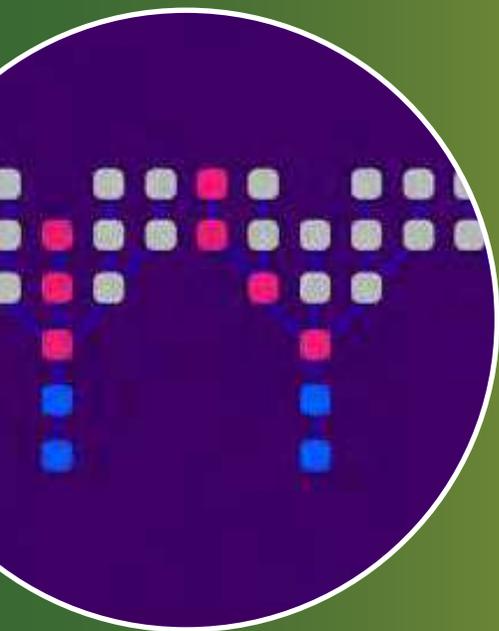
The disruptive impact comes from the ability for staking to align incentives for participants in a given network.

EMERGING PLAYERS

- Ethereum
- Compound
- Aave

1ST YEAR ON THE LIST

Smart Oracles



Polkadot says it's facilitating an internet where independent blockchains can exchange information and transactions in a trustless way.

KEY INSIGHT

Price indexes, stock markets, and other economic indicators are used to determine the health and wellness of economic activity. While these data sources are updated regularly, it's not happening continuously throughout the day. Cryptocurrencies and tokens operate 24/7, making it possible to create smart oracles for economic indicators in near-real time.

EXAMPLES

In the U.S., the Bureau of Labor Statistics publishes economic indicator reports such as jobs numbers and the consumer price index on a monthly basis. The NYSE operates from 9:30 a.m. to 4 p.m. Eastern time and closes during bank holidays. Projects like Chainlink allow anyone to connect their API to a public network and monetize that data, making market information available 24/7. Projects like Polkadot enable information to flow seamlessly between blockchains. This type of data analytics already happens today to some degree with companies like Oracle and Palantir. They use a combination of external databases, customer data, relational database architecture, and AI to draw business insights for their clients. Now imagine if that level of analytics was made publicly available. Imagine connecting weather information with Amazon pricing information and stock market data to your smart home device.

DISRUPTIVE IMPACT

Asymmetric information leads to a competitive advantage. Many companies pay top dollar to have their data analyzed and interpreted for strategic insights. Smart oracles built on blockchain enable smart contracts to use real-world data as inputs. Depending on how this trend evolves, we may see a democratization of data analytics or a handful of companies with surveillance programs that rival the U.S. government. From a public good perspective, we may see communities electing to put major datasets on-chain and creating a community dashboard. Either way, big data is only becoming more interconnected and interoperable.

EMERGING PLAYERS

- Chainlink
- Polkadot
- Palantir
- Oracle

I don't want new folks entering into crypto to feel like they're transitioning from old Wall Street to new Wall Street. I want the environment to feel approachable and inclusive.

— Kinjal Shah, senior associate at Blockchain Capital



Non Fungible Tokens (NFTs)

2ND YEAR ON THE LIST

Non Fungible Tokens



Adoption of NFTs has skyrocketed over the past year, and the tokens are being used to purchase everything from digital art to digital property.

KEY INSIGHT

Blockchains enable digital tokens that are provably unique and scarce. Digital collectibles saw an early start in areas like eSports, online gaming, and social networks, but have seen an explosion of growth over the past year in artwork and media. The application of these tokens continues to expand across commerce and investing, in addition to extending the breadth of personal art collections.

EXAMPLES

NFTs have been available to the masses for several years, beginning with the minting of Terra Nullius on the Ethereum blockchain back in 2015. Despite relatively slow growth after that launch, the adoption and sale of NFTs grew exponentially in 2021. Bored Ape Yacht Club was one of the most popular NFTs of the year, with some reaching a price of nearly \$3 million. Many popular companies and public figures followed, with well-known brands such as Christie's and Nike launching their own NFTs, as well as releases by Tom Brady, Grimes, and Snoop Dogg.

Ubisoft and EA began to explore pay-to-play type business models that leveraged NFTs to purchase new game features. In this model, players would receive in-game NFT collectibles. However, many players pushed back due to the environmental concerns that surround NFTs, because of the amount of energy it takes to mine a blockchain, as well as the amount of time it would take for players to earn such tokens.

DISRUPTIVE IMPACT

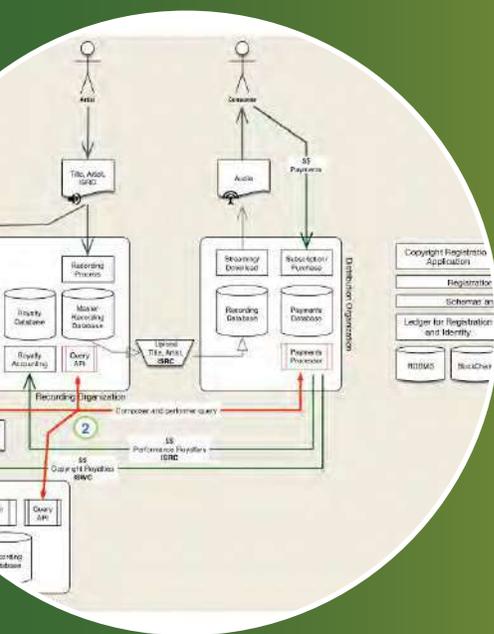
Digital collectables are not the long-term trend here—the infrastructure is. Watch for minting and authenticating assets as one's own in a virtual world—a capability that will be a cornerstone to the development of Web 3.0 and the metaverse. NFTs in the future will likely be used to monetize other types of property. Personal data will benefit from standardized tokenization, by allowing individuals to verify that data is one's own. Additionally, NFTs will be attached to real-world items, such as cars, clothing, or luxury handbags, allowing for an authentication chain that validates ownership, and for future owners of that real property to trace its history.

EMERGING PLAYERS

- OpenSea
- Christie's Auction House
- Snoop Dogg
- Nike
- NBA
- Roblox
- Rarible
- Gucci
- LVMH
- SuperRare

5TH YEAR ON THE LIST

Smart Royalties



KEY INSIGHT

Blockchain networks offer new ways to track ownership, licensing, and royalties through smart contracts, or self-executing agreements with terms directly written into lines of code.

The Open Music Initiative is working to solve many royalty payment gaps within the music publishing industry. The red lines are aspects of the OMI's process and API that ensure fair payments to each artist and contributor.

EXAMPLES

Blockchains form the foundational infrastructure layer for new, low-friction ways to automate royalty payments for digital intellectual property. A smart contract, for instance, would automatically pay an artist when her song is streamed or simply track the number of times people share online content, preserving it in a shared public database.

ConsenSys Mesh is debuting an NFT platform called TreeTrunk on the Polygon Mumbai testnet. Tree Trunk collects and distributes royalty payments from secondary sales of NFTs using a method called crypto-lithography, which allows artists to create unique and numbered prints or copies of their work. This method will ensure that artists' material is protected from fraudulent copies, and that artists will receive royalty payments from subsequent sales of their content. Metablaze is releasing a collection product that aims to do the same thing, and incorporates NFT based perpetual royalties set on the Ethereum blockchain.

DISRUPTIVE IMPACT

This type of royalty authentication could be used in a vast array of applications moving forward. Most obviously, content creators will have better mechanisms for maintaining their rights to their content and subsequent payments. Additionally, however, this same model could be applied to any other form of content that could yield a micropayment upon usage—individual likenesses, aspects of personal data and information, new articles and reports that sit behind paywalls, photographs, and many more. Currently, much of the content online is available broadly and publicly, even if the content creator intends for there to be limitations on its use. This type of tracking and verification mechanism could change the nature of accessing and sharing information—and more specifically, the value that information holds.

EMERGING PLAYERS

- Associated Press
- Ethereum
- Mycelia
- Open Music Initiative
- Berklee College of Music
- ConsenSys Mesh

1ST YEAR ON THE LIST

Monetizing Memes



Side Eyeing Chloe, a popular meme for expressing concern or disapproval, sold for 25 ETH in September 2021—just over \$76,000 at the time of sale.

KEY INSIGHT

Internet memes are viral images that spread across the web. Chef Salt Bae parlayed his viral moment into a chain of steakhouses, but otherwise the subjects in those images rarely receive any compensation despite their wild popularity. NFTs are empowering meme makers to monetize their original work after it becomes viral.

EXAMPLES

In 2021, NFTs of Disaster Girl and Bad Luck Brian sold at a digital auction, commanding \$500,000 and \$36,000 respectively. Many recent popular memes sold have all been purchased by a single buyer. Disaster Girl along with Charlie Bit My Finger, Overly Attached Girlfriend, and Side Eyeing Chloe were purchased by 3F Music, a Dubai-based music producer. The sales did not include transfer of copyright.

DISRUPTIVE IMPACT

It might be hard to understand why someone would pay for a picture that is widely distributed throughout the internet, but in the near future, all memes may be monetized. NFTs have the power of making digital images scarce. As a meme becomes more popular or goes viral, there is value in proving that an influencer or brand was an early adopter or one of the first “in the know.” Not only can the subjects of memes capitalize on their likeness, future memes can also be leveraged as a means of distributing tokens or building online communities.

EMERGING PLAYERS

- OpenSea
- Bequant
- Discord
- TikTok
- Instagram

1ST YEAR ON THE LIST

Proof of Everything



Collect badges for everything you've attended and store them in your POAP NFT wallet. These digital momentos show others where you've been and what you've experienced.

KEY INSIGHT

One characteristic of blockchains is the permanent history of transactions broadcasted on a public ledger. NFTs can act as badges that prove your membership in a group, your attendance to an event, and even certain skills on your résumé.

EXAMPLES

A POAP badge is an NFT that proves your attendance to an event. RabbitHole.gg is a platform that lets you transform your digital wallet into a Web 3.0 résumé by completing certain tasks. The World Food Program was criticized for a blockchain pilot program that required refugees to scan their irises in order to get their food stipend.

DISRUPTIVE IMPACT

Digital proofs will become more common as we spend more of our lives in a digital (and therefore borderless) world. Proof of everything also means ubiquitous surveillance and new social norms for establishing trust and building rapport.

EMERGING PLAYERS

- RabbitHole
- Everything Blockchain



Knock-on Trends

1ST YEAR ON THE LIST

Crypto Mining Fuels Green Energy



The energy-intensive nature of cryptocurrency mining is driving the industry to search for renewable energy solutions to support the work.

KEY INSIGHT

Crypto mining provides security to the Bitcoin network by rewarding computers for validating transactions, but it's widely criticized for being energy-intensive. A new generation of crypto mining companies is focusing on renewable or otherwise green energy to fuel their operations.

EXAMPLES

For years, crypto miners have leveraged wind and geothermal and hydro energy as sources for cheap electricity to mine Bitcoin and other currencies. El Salvador mined the first bitcoin using volcanic energy in the summer of 2021. In El Salvador, 22% of the energy comes from geothermal activity such as volcanoes. In the U.S., entrepreneurs are establishing mining operations near fossil fuel plants in order to capture energy that would otherwise go to waste or reduce pollutants entering the atmosphere. HODL Ranch in Texas operates using the state's wind and solar energy, and has an agreement with the state to suspend mining operations when the electric grid experiences a surge in demand. Crusoe Energy Systems sets up mining operations using natural gas near pipelines that would otherwise be burned off in flares. MintGreen, a Canadian cleantech startup, will provide heat to the city of North Vancouver using electricity from mining bitcoin.

DISRUPTIVE IMPACT

Bitcoin mining is spurring a conversation on what should count as "green" energy and what counts as energy waste. Beyond bitcoin, this trend will challenge communities to be more creative with how energy grids are designed, managed, and monetized, eventually resulting in a better alignment of sustainability and profit.

EMERGING PLAYERS

- Compass Mining
- El Salvador
- Galaxy Digital
- HODL Ranch
- MintGreen
- Riot Blockchain

1ST YEAR ON THE LIST

Community Dashboards



The city of Asheville, North Carolina, launched a dashboard in early 2022 that provides point-in-time data on homelessness.

KEY INSIGHT

Governments have reams of information that would benefit their citizens if only it was easier to access and understand. Decentralized databases, powered by blockchain, could enable secure and transparent community dashboards on everything from water quality to city budgets, improving public trust and civic engagement.

EXAMPLES

Throughout the COVID-19 pandemic, communities worldwide produced dashboards to track outbreaks, infections, and vaccination rates. Some of these efforts were managed by municipal health departments while others were the results of civilian volunteer efforts.

In addition to a slew of COVID-19 and public safety-related dashboards, communities are experimenting with these centralized data hubs for a variety of other applications. In February 2022, the Indiana State Board of Education released a first look at its new dashboard. The hub provides information about the state's public K-12 schools across five key areas: academic mastery; career and postsecondary experiences and credentials; collaboration and communication skills; work ethic; and digital, financial, and civic literacy. The city of Asheville, North Carolina, launched a different kind of dashboard in early 2022, one that provides point-in-time data on homelessness in the city.

DISRUPTIVE IMPACT

Community dashboards are a likely outcome as movements toward open government and civic tech gain popularity and local newsrooms continue to disappear. As more people have access to public information, more groups can monitor them to ensure accuracy. While people have grown accustomed to the notion of governments surveilling their citizens, citizens surveilling their governments is an exciting new paradigm for accountability and public services.

EMERGING PLAYERS

- Taiwan
- Indiana State Board of Education
- Asheville, North Carolina
- Virginia Department of Health



For a long time, Web3 has been very theoretical, but now there is a surge of momentum to build.

— Elon Musk, CEO, Tesla



How these trends impact your company



STRATEGY

Innovative use cases for blockchain abound, but the complexity of the ecosystem remains a hurdle for most companies. Given the meteoric rise of NFT popularity and metaverse buzz over the past year, many organizations have raced to invest, purchasing digital land or assets on which they cannot easily calculate their return. Disorganized experimentation without strategic positioning jeopardizes positive outcomes and returns on investment. Chief strategy officers should take the time to evaluate current internal needs and identify areas of potential investment in blockchain or NFTs that will help them achieve their near- and mid-term goals.



INNOVATION

Companies interested in blockchain often struggle to find meaningful use cases, but recent developments of new decentralized, blockchain, and/or NFT offerings have revealed a possible solution or offering for nearly any need. Chief innovation officers should work within their organization to identify capability gaps. Is more, and more efficient, data collection needed? Are consumers demanding new ways of interacting? Or does the organization need a new way to deliver value to the market? Once a set of strategic needs has been addressed, a blockchain or decentralized solution likely exists that can be smartly leveraged to help the company see the benefits of such innovation in the near term.



R & D

Once viewed as falling squarely in the financial services industry, companies across all industries are beginning to see the possible applications of decentralized or blockchain technology. There continues to be a need for experts in a variety of fields to experiment with decentralized solutions and identify current problem areas for which these technologies could be a good fit. Focused investment and experimentation in this space to validate potential success could help companies both learn more about this evolving space and become the first beneficiaries of their own exploration.



GROWTH

In the longer term, business models will be forced to transform as financial markets are increasingly penetrated by new value mechanisms, smart contracts become the norm for agreements and terms, and methods of value creation evolve. Organizations must begin now to evaluate the various business practices that could be most disrupted by this shift, and identify ways to begin their transition and transformation, in order to be prepared for the changing dynamics as they emerge.

Key Questions

We recommend using this report to support your strategic foresight activity in the coming year. Every executive team should begin by asking these questions:

1

- ▶ How will blockchain and decentralized finance change the way we conduct transactions with our customers, employees, and supply chain?

- ▶ How could blockchain-based assets such as cryptocurrency and NFTs be used to create new or added value from our existing business offerings?

2

- ▶ What new systems or data collection mechanisms would we need to implement to succeed in this new paradigm?

- ▶ What new types of data might we be able to collect on our business and our customers using these solutions, which could be converted into deeper insights about our operations and offerings?

3

- ▶ What parts of our business are the most ripe for disruption brought about by NFTs, cryptocurrency, digital currency, and decentralized technology?

- ▶ What can we do today to begin preparing for this new way of doing business?

Selected Sources

https://home.treasury.gov/system/files/136/StableCoinReport_Nov1_508.pdf

<https://doi.org/10.3390/computers10080090>

<https://web3.foundation>

<https://c2pa.org>

<https://scholarship.law.vanderbilt.edu/cgi/viewcontent.cgi?article=1044&context=jetlaw>

<https://www.urban.org/urban-wire/adopting-alternative-data-credit-scoring-would-allow-millions-consumers-access-credit>

<https://www.natlawreview.com/article/tech-transactions-data-privacy-2022-report-content-distribution-blockchain-case>

<https://doi.org/10.1155/2021/2613656>

<https://milkyway.cs.rpi.edu/milkyway>

<https://cointelegraph.com/news/new-consensus-mesh-nft-marketplace-pays-royalties-to-creators-and-collectors>

<https://www.sec.gov/Archives/edgar/data/1830214/000119312521275407/d172577d424b3.htm>

Ethereum.org. "Ethereum Whitepaper." Accessed Feb. 19, 2022, <https://ethereum.org>.

<https://github.com/mit-dci/openbc-dc-tx>

<https://static1.squarespace.com/static/59aae5e9a803bb10bedeb03e/t/61fc25f91a0df9037488eb7d/1643914745989/Hamilton.Whitepaper-2022-02-02-FINAL2.pdf>

<https://dci.mit.edu/openbc-dc>

"Venture Capital, Private Equity, and M&A Database | PitchBook." Accessed Dec. 22, 2021, <https://pitchbook.com>.

<https://www.bloomberg.com/news/articles/2021-11-04/nyc-mayor-elect-eric-adams-says-he-ll-take-paycheck-in-bitcoin>

<https://financialservices.house.gov/events/eventsingle.aspx?EventID=408111>

<https://www.sec.gov/news/public-statement/gensler-aspen-security-forum-2021-08-03>

<https://www.reuters.com/world/china/china-central-bank-vows-crack-down-cryptocurrency-trading-2021-09-24>



Telecommunications & Computing

5G, 6G, networking, edge computing and quantum computing influencing the future of telecommunications and computing.



Table of Contents

511	Key Insights	529	Big Tech Companies at the Edge
512	The 5G Economy	529	Serverless Edge
514	5G	530	Scenario: When Your Clothing Controls You
515	Private 5G Networks	531	Quantum
516	5Geopolitics	532	Quantum Computing
517	Scenario: Florida Man Charged with Stealing from Neighbors	534	Quantum Computing Trends
518	6G	534	Quantum Internet
519	Breaking the Millisecond Barrier	534	Autonomous Quantum Design
520	Networking	534	Self-Repairing Quantum Systems
521	Network-as-a-Service (Naas)	534	Quantum Supremacy
522	Scenario: Dog Taxi	535	Global Quantum Computing Race
523	Network Trends	536	Quantum Boosts for Classical Computers
523	Zero-Touch	536	Updating Post-Quantum Cryptography Standards
523	Satellite-Based Internet Services	536	Light-Based Quantum
523	Mesh Networks	538	Application
524	Securing Distributed Infrastructure	539	Key Questions
524	Location-Aware Wi-Fi	540	Selected Sources
524	Adoption of Hybrid Cloud		
525	Edge		
526	Edge Computing		
528	Edge Trends		
528	Near-Real-Time Application Environments		
528	AI at the Edge		
528	Edge Management		

Key Insights

- * 5G is the fifth generation mobile network and a global wireless standard. Despite a slow initial rollout, 5G is expected to expand significantly in 2022, beginning with network upgrades early in the year.
- * Spectrum for private use will be available in 2022, enabling owners to build private 5G networks for organizations.
- * Significant decoupling has occurred in recent months, splitting the 5G players into “China” and “not-China” categories.
- * Geopolitical players vying for influence in the 5G space have more than just market penetration to gain—political ideology (specifically around privacy and access) is embedded in technology policy, and the winner of this battle will set the tone for the remaining century.
- * 6G will be the sixth generation of wide-area wireless technology, following the transition to 5G. Although experts place the timing of a 6G launch between 2028–2030, many industry leaders are already working to understand and define this new standard.
- * Thanks to the cloud, NaaS services are flexible and inherently more scalable than older network configurations.
- * Zero-touch will disrupt how we build, run, and operate new services.
- * Space-based internet could further squeeze the margins of communications service providers across the globe and render them less relevant.
- * Edge computing will increasingly be deployed to facilitate near-real-time experiences and applications, especially as the number of connected devices grows.
- * Early steps to build a quantum internet are already in progress.
- * The global quantum computing race is well underway. Several nations, including the U.S., France, the U.K., and China, want to become the global leader in quantum computing.
- * Two major instances of light-based, or photon-based, quantum computing systems were developed in the last year, illustrating a quantum computing method that is more effective than using superconductive materials.



The 5G Economy

5G is going to underpin significant megatrends in our society.

— David Christopher, executive vice president and general manager of partnerships and 5G ecosystem development, AT&T

5TH YEAR ON THE LIST

5G



5G is the fifth generation of wireless connectivity.

KEY INSIGHT

5G is the fifth generation mobile network and a global wireless standard. Despite a slow initial rollout, 5G is expected to expand significantly in 2022, beginning with network upgrades early in the year. 5G promises high speeds, ultra low latency, and the ability to connect billions of devices.

EXAMPLES

5G utilizes new radio interfaces and higher frequencies to transfer more data at faster speeds and lower latency. The wireless network leverages low-band, mid-band, and high-band spectrums to make connectivity available at various capacities and speeds. Though launched in 2019, 5G is just beginning to reach meaningful scale in 2022, beginning with a new C-band (mid-band spectrum) upgrade by AT&T and Verizon (in the U.S.) early in the year that will make 5G accessible to individuals across a broader geographic area. 5G offers download speeds of up to 1 gigabit per second—significantly faster than previous networks such as 4G LTE—and latency of 1 millisecond, making downloads and connections feel almost instantaneous. Monetization of 5G has been challenging for network operators due to costly deployments and a dearth of B2B use cases. However, growing interest around immersive and highly connected capabilities and experiences could help bolster demand, creating improved business models.

DISRUPTIVE IMPACT

The benefits of 5G span myriad industries and applications. At CES 2022, Qualcomm unveiled its Snapdragon Digital Chassis, developed in partnership with Renault, which promises always-on connectivity. Remote training for health care practitioners will be possible through augmented reality applications where instructors can place their hand in a trainee's field of vision, something the U.S. Department of Defense is testing now. The metaverse is an obvious beneficiary of 5G, due to its dependence on fast and zero-lag interactivity. Real estate owners could also achieve new income streams by making their rooftops available for 5G deployment by network operators. However, 5G deployment can create unintended challenges. In early 2022, C-band upgrades were initially delayed after aircraft makers voiced concerns that the new connectivity would leverage radio frequencies extremely close to the ones they use—potentially creating disruption or safety hazards for airplanes.

EMERGING PLAYERS

- 5G Fund for Rural America
- AT&T
- Ericsson
- Google
- Huawei
- LG
- National Spectrum Consortium
- Nokia
- Open Radio Access Network (O-RAN)
- Qualcomm
- Samsung
- Spectrum Forward Other Transaction Agreement
- T-Mobile
- U.S. Department of Defense
- Verizon

2ND YEAR ON THE LIST

Private 5G Networks



Private 5G networks will catalyze the growth of smart factories.

KEY INSIGHT

Spectrum for private use will be available in 2022, enabling owners to build private 5G networks for organizations.

EXAMPLES

Private 5G is a mobile network that's similar to a public 5G network, with some enhancements. Like public 5G networks, private ones offer gigabit speeds and lower-latency and higher-throughput connectivity. Private networks can be deployed within the confines of just one location—such as a manufacturing plant—where always-on connectivity is required for machinery, computer systems, and logistics. For example, a private 5G network would enable an auto manufacturing plant to move parts along an assembly line using connected robotics. A private network can be configured to afford certain machines priority over others, and enable an operator to prioritize or deprioritize activities as needed, depending on what activities are underway at a given time.

DISRUPTIVE IMPACT

Because private networks give local operators more control over access points and devices, they can be more secure. By controlling access and deprioritizing activities, private networks can limit or even isolate exposure to third parties, which could serve as added protection against the theft of employee information, data, and intellectual property. As collaborative robots become more specialized and organizations adopt self-driving machines, build digital twins, and bring augmented reality into the enterprise, private 5G networks will unlock compelling use cases in smart factories, hospitals, high-tech farms, government agencies, and many other industries.

EMERGING PLAYERS

- AWS Private 5G
- Comcast Business
- Nokia
- Ericsson
- AT&T

5TH YEAR ON THE LIST

5Geopolitics



In 2021, Millicom became the first telecom operator in Latin America to deploy an O-RAN network in partnership with Parallel Wireless.

KEY INSIGHT

The battle for 5G influence has shifted. Continued pressure on previously dominant Chinese 5G leaders has created an increasingly bifurcated deployment.

EXAMPLES

Banned Chinese companies Huawei and ZTE sought relief from their restrictions when the Biden administration took office. However, the past year has shown that U.S. foreign policy is increasingly inextricably linked with technology—5G and 6G in particular—and the determination of the U.S. to openly compete with China in these areas is being solidified as a bipartisan value. In addition to these two market leaders, numerous other China-based technology and microelectronic companies were added in 2021 to the list of companies not allowed to do business in the U.S. Though Ericsson and Samsung have benefited enormously in the U.S., they've faced challenges in the Chinese market, including falling China revenues. Ongoing pressure on Chinese players in the U.S. has also created opportunity for newer, smaller American companies to expand into the market.

DISRUPTIVE IMPACT

The battle for foreign influence over developing geographies, particularly those in Africa and Latin America, is increasingly waged in the context of 5G and 6G, driving foreign policy decision-making in the United States and abroad. Latin American leaders in particular have worked hard to maintain positive relations with both China and the United States. In 2021, mobile service provider Millicom was the first to bring O-RAN (Open Radio Access Network) compliant networking to Latin America, signaling that network providers there will be open to working with companies from varying geographic regions.

EMERGING PLAYERS

- Airspan Networks
- AltioStar
- Ericsson
- Huawei
- JMA Wireless
- Mavenir
- National Democratic Institute
- Nokia
- Open Radio Access Network (O-RAN)
- Parallel Wireless
- Samsung
- ZTE

The Florida Sun Times

SUNDAY, MARCH 13, 2033

Florida Man Charged with Stealing Power from Neighbors

By Sadie Reutman

Police arrested an Apalachicola man Tuesday for allegedly hacking his neighbor and selling his computing power.

Police say Archibald N. Bouvier, 26, hacked into his community's Amazon Sidewalk mesh network and sold his neighbors' spare computing power on the Conflow distributed computing network. By the time law enforcement identified Bouvier and tracked his location, he allegedly earned more than \$10,000 from the scheme. He faces charges of one count of grand theft.

"The HOA said people were complaining about slow internet speeds, but it took months to isolate

the issue," Pittsburgh Police Chief Bill Bratt said. A happenstance admin message detected last month provided the only lead.

Bouvier allegedly purchased malware online that let him infect one neighbor's connected car and granted him access to other devices connected to the mesh network. He proceeded to infect more households one by one, police said. The hacks might not have been detected, until the man started renting out the computing resources at all hours of the day.

If convicted, Bouvier faces a maximum of 30 years and a fine of up to \$10,000. In cyber cases, judges

may also restrict access to computing devices upon conviction.

Linda Nottingham, Bouvier's lawyer, said her client's actions were legal under the Sidewalk terms and conditions. "My client will continue to claim his right to access computing resources that were freely offered on the mesh network," she said.

Assistant District Attorney Ronan Dotter stated in a press conference that the district would pursue the case with rigor to deter copycats.

Bouvier is scheduled to appear in court on July 30.

5TH YEAR ON THE LIST

6G



6G will be the sixth generation wireless network.

KEY INSIGHT

6G will be the sixth generation of wide-area wireless technology, following the transition to 5G. Although experts place the timing of a 6G launch between 2028–2030, many industry leaders are already working to understand and define this new standard.

EXAMPLES

6G is still a nascent standard, but industry leaders do not want to be caught unprepared. Several key players launched research or experiments in 2021 to grow their understanding of the technology. SoftBank and the Next Generation Mobile Networks Alliance released their concepts for 6G. Hexa-X, an industry consortium that includes Nokia and Ericsson, released a white paper that aims to answer questions around the technical infrastructure of a 6G network, as well as potential use cases and applications. In June 2021, Samsung and the University of California, Santa Barbara successfully demonstrated a 6G terahertz wireless communication prototype, achieving real-time throughput of 6.2 gigabits per second over a 15-meter distance.

DISRUPTIVE IMPACT

6G is not 5G+. If achieved in its full potential, 6G will support throughput/data rates up to 1 terabyte per second and latency of 10–100 microseconds, removing any present issues of capacity. This type of capability will support the realization of possibilities such as true telepresence, immersive smart cities, and scaled telesurgery. Holographic technologies, which cannot be supported at scale with existing 4G or 5G bandwidth, are likely to scale in number and frequency of applications as 6G becomes available, enabling a realistic rendered local presence in a variety of settings. Other senses, such as smell and taste, could be incorporated to enrich virtual experiences, building upon nascent proprioceptive mixed-reality capabilities.

EMERGING PLAYERS

- Beijing University of Posts and Telecommunications
- Ericsson
- Hexa-X
- Huawei
- Next G Alliance
- Nokia
- NTT DoCoMo
- Samsung
- Skolkovo Institute of Science and Technology
- SoftBank
- University of Oulu
- University of Padova
- University of Surrey
- University of Texas at Austin 6G@UT
- ZTE

2ND YEAR ON THE LIST

Breaking the Millisecond Barrier



A new 1 millisecond standard for latency is being developed.

KEY INSIGHT

Latency, or the amount of time it takes for data to be transmitted from one place to another, currently ranges from about 15 to 44 milliseconds, depending on whether you are using fixed broadband or satellite internet. New protocols could lower that speed to just 1 millisecond.

EXAMPLES

Latency causes problems in applications that require real-time experiences, such as gaming, videoconferencing, and VR. The number of devices using a network and the amount of data being exchanged contribute to increased latency. As more and more devices, people, and activities rely on connectivity, latency poses a significant challenge. Various players have created new standards and protocols to achieve decreased latency. The U.S. Department of Defense has leveraged Open Radio Access Network standards to create a prototype network that delivered sub-15 millisecond latency. CableLabs, creator of DOCSIS 3.1 (which stands for data-over-cable service interface specifications), announced in April 2021 that it had certified the first DOCSIS 3.1-compliant cable modem—a key step in making lower-latency connectivity available. Reducing latency won't just make everyday life more seamless; it will also enable the emergence of key new technological capabilities.

DISRUPTIVE IMPACT

Growth and development in many industries are almost certain to result in an ultra low latency environment. Autonomous vehicles will be able to realize the full benefits of cooperative perception, by communicating upcoming obstacles and congestion with surrounding vehicles in real time. Health care examinations, procedures, and surgeries performed remotely in real time, leveraging haptic technologies, assistive robotics, and augmented reality, will become possible and safe. Synthetic media will be applicable in real-time scenarios, such as instantaneous translation during a videoconference, making it appear as though meeting participants are speaking in each other's native language. Ultra low latency also promises to upend high speed trading and financial services, enabling seamless participation in global financial markets, and instant execution of trades.

EMERGING PLAYERS

- CableLabs
- Internet Engineering Task Force's L4S
- Kyrio
- NCTA
- NYU Wireless
- U.S. Department of Defense



Networking

1ST YEAR ON THE LIST

Network-as-a-Service (NaaS)



NaaS models are cloud based and eliminate the need for organizations to set up and maintain their own network infrastructure.

KEY INSIGHT

Cloud advancements have unlocked an emerging network operating model that no longer requires organizations to build, own, or maintain their own infrastructure.

EXAMPLES

Network-as-a-service (NaaS) broadly defines a new model for network consumption, which is externally managed by a service provider and is subscription- or consumption-based, much like the cloud consumption model. Traditionally, companies would need to make a big capital investment in physical, static, hardware-based appliances, switches, load balancers, and virtual private networks. Rather than investing in capital-intensive physical networks, NaaS uses an operating expense model and includes hardware, software, maintenance, monitoring, patching, provisioning, and service. The different NaaS variations available today range from MVNOs (mobile virtual network operators) to SASEs (secure access service edge).

DISRUPTIVE IMPACT

Organizational computing needs are becoming more complex, and NaaS models build in optionality: External or internal IT managers can deploy services to distributed workforces, with low-latency connectivity and limited packet loss when engaging with a company's software-as-a-service applications or other high-value services. Early NaaS technologies offer greater security than the last generation of networks. Thanks to the cloud, NaaS services are flexible and inherently more scalable than older network configurations.

EMERGING PLAYERS

- Cisco Plus NaaS
- Cloudflare Magic WAN
- Akamai Aura Managed CDN
- Perimeter 81
- Palo Alto Networks Prisma
- Amazon Web Services

Dog Taxi • Mid-future optimistic scenario

5G has enabled hyperlocation and connectivity from anywhere. It also paved the way for GuardMyDog™, which harnesses the power of 5G and small autonomous vehicles to chauffeur pups to doggy day cares. Most doggy day cares connect with the GuardMyDog network, so they can provide both vast outdoor playgrounds and on-demand fleets of dog taxis.

We're headed out of the city for a couple days. Leaving tonight. Wanna come?

Ohhhh, sounds great! But not sure I can find a dog sitter for Cosmo.

Wait, what? What about GuardMyDog? They'll send a taxi. Are you home?

What's GuardMyDog?

Download their app! Enter the dates you need a dog sitter, the type of dog you have, and they'll send an autonomous taxi to pick up Cosmo and bring him to a highly rated doggy day care! The taxis are so great— they've got food, water, treats, and a dog bed so the doggies can rest, and a self-cleaning floor that keeps the taxi clean!

You can even track him through their app, using a smart collar. The doggies love it! 🐾 Mine is always bummed to come back! 😊

I'll be at Robert's on Monday, though, so I won't be home for a few days.

They'll send the taxi w/Cosmo to wherever you are. They're nationwide!

See you later then 🐾



Network Trends



Zero-touch systems will eventually enable self-healing services for networks.

■ Zero-Touch

What if networks could automatically diagnose and heal themselves? What if they could understand your intentions and respond correctly, in the moment? Reducing the need for human intervention isn't simply about automation—zero-touch moves beyond that to anticipate needs using artificial intelligence and machine learning. Next-generation networks will need to meet always-on expectations for service and to stay competitive. Zero-touch will disrupt how we build, run, and operate new services. It changes the roles people play within traditional businesses—the way we allocate resources, respond to customer needs, and mitigate threats. For example, Norwegian communications service provider (CSP) Telenor has simplified network slicing with zero-touch digital orchestration. Comcast Business launched a new offering that uses AI to detect and respond to service degradation without the need

for operator intervention. Traffic is then automatically prioritized and rerouted around network failures.

■ Satellite-Based Internet Services

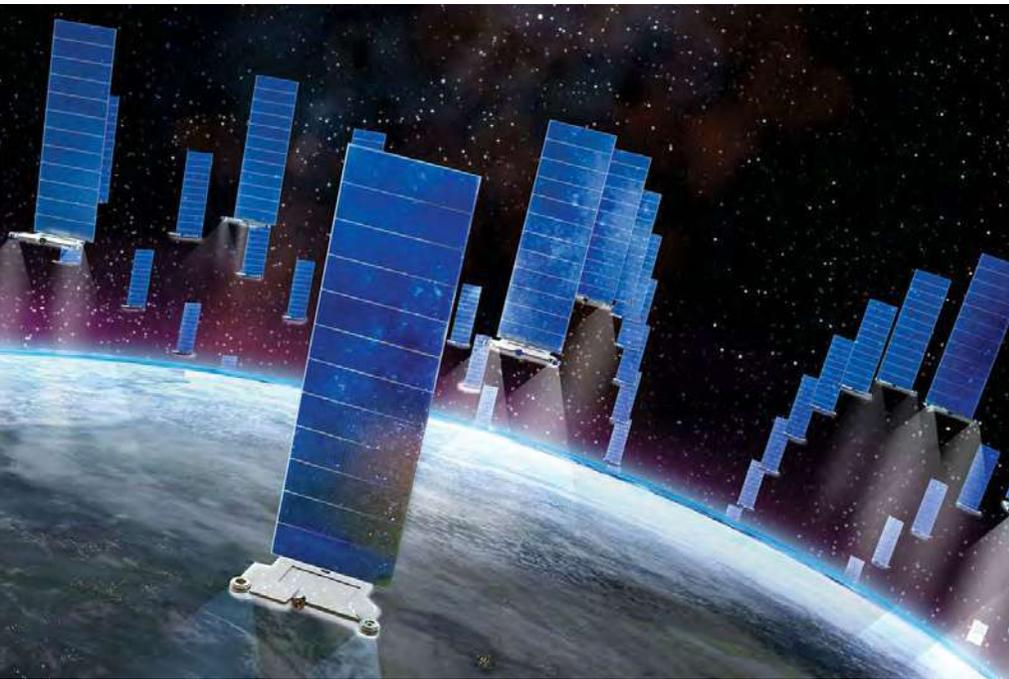
Amazon, SpaceX, and others are developing satellite technology that would beam internet services directly to the enterprise and consumer devices, and in the process bypass internet service providers. Space-based internet will eventually be capable of fast, low-latency connectivity anywhere in the world without extensive ground infrastructure. There is a vast array of companies with planned “microsat” or “cubesat” launches over the next five years. The addition of intersatellite laser crosslinks enables peer-to-peer communications and minimizes the need for ground stations. The result is fast internet in remote areas with little ground infrastructure investment. All of this could further

squeeze the margins of CSPs across the globe and render them less relevant.

■ Mesh Networks

A mesh network is a group of devices within close proximity that enables fast and efficient data routing. Amazon's Sidewalk program is a location-tracking mesh network operating at the scale of a neighborhood that utilizes consumer devices already connected via CSPs or ISPs. It plans to link its ecosystem of smart home devices like Ring and Echo using Bluetooth low-energy and unlicensed spectrum like the 900MHz band. Sidewalk pools internet bandwidth from devices within a half-mile that have the service turned on. The more neighbors who participate, the more bandwidth the mesh network has. It can transmit software and security updates, too. One early use case: If a consumer loses her keys attached to a Tile device, she can use the Sidewalk network to automatically locate where she left them.

Network Trends



SpaceX plans to eventually operate more than 40,000 satellites in its megaconstellation.

This technology offers a compelling convenience factor. If, for some reason, a consumer's Wi-Fi goes down, he can temporarily continue to stay online but with limited bandwidth (80 kilobits per second). Sidewalk needs ISPs to function, but it has inserted itself into the consumer relationship with those providers.

■ Securing Distributed Infrastructure

Few companies house all of their data, equipment, and IT infrastructure under one roof. They rely instead on managed service providers, third-party cloud providers, data centers, and the like. As technology becomes more sophisticated, IT becomes increasingly distributed, making it challenging to safeguard both those systems and their supply chains. Given the large number of cyberattacks on organizations in 2021 (and already in 2022), IT professionals are seeking new ways to secure distributed infrastructure.

■ Location-Aware Wi-Fi

A decade ago, Google was working on indoor positioning systems—like a GPS, but for buildings—in order to help users navigate the great indoors. It was granted patents in 2017 for a system that uses IPS (indoor positioning system), LEDs, and Wi-Fi to make indoor navigation more accurate. The Fine Time Measurement protocol will enhance location dramatically, and as it is built into newer Wi-Fi systems, indoor navigation will gain more utility. Location-aware Wi-Fi will also make it easier on network administrators to locate and scrape access point data as needed.

■ Adoption of Hybrid Cloud

The three biggest cloud providers in the U.S.—Microsoft, Amazon, and Google—have collectively invested tens of billions of dollars building infrastructure: data centers, monitoring systems, and software. These robustly designed

systems prevent downtime and data loss, and few other companies in the world can compete. But the cloud isn't public infrastructure; it's private. And as private companies, cloud providers currently control access to their services—services that are becoming the lifeblood of businesses. These private companies sometimes compete with the cloud provider's offerings as well. Take Netflix, for example. It runs its streaming business on Amazon Web Services, which is in direct competition with Amazon Prime's streaming service. A concentrated market for an invaluable service creates high risk. It can take several years for a large company to integrate its data into the cloud, making selection a high-stakes choice and the cost of switching prohibitive. Some companies are now looking to hybrid models, which offers a computing environment that makes use of an on-premises data center with a public cloud.



00

01

02

03

04

05

06

07

08

09

10

11

12

13

Telecommunications & Computing

Edge

5TH YEAR ON THE LIST

Edge Computing



Edge computing allows for data storage and analysis on the individual device, improving performance, speed, and security.

KEY INSIGHT

Edge computing performs computations near or at the source of data. As the amount of data collected and generated grows, edge computing can provide a solution that is faster, safer, and more efficient than cloud computing solutions.

EXAMPLES

Edge computing differs from the current norm, as much of today's computing takes place in the cloud, with distributed data centers handling the processing work. It addresses some of the limitations of cloud computing, such as data security and privacy concerns, and data-transfer delays preventing immediate analysis. Edge computing requires custom hardware, but many leading technology companies are already offering such products today, including some meant for niche use, such as Amazon Web Services' Snow Family, which provides edge devices of all sizes to suit needs ranging from individual remote data storage and analysis to the relocation of entire data centers.

DISRUPTIVE IMPACT

One key beneficial application of edge computing is swarm intelligence, which allows the insights and learnings gathered from decentralized data sources to be grouped together in a way that retains the security of the data on the edge, while providing a wider set of learnings to each user. Edge computing offers myriad benefits to many industries. Health care applications include the sharing of anonymized insights that protect patient privacy while enhancing diagnostics and providing patient-specific solutions, such as automated insulin delivery systems using artificial pancreas sensors under the skin to detect when insulin is needed. Autonomous vehicles are another area that will require meaningful edge capabilities. Due to the nature of driving, these vehicles will not be able to wait for a command after sending data to a cloud-based platform for analysis; they will need to make split-second decisions—something only edge capabilities can provide at scale.

EMERGING PLAYERS

- AWS IoT Greengrass
- AWS Snow Family
- Cisco Catalyst IR8100
- Dell PowerStore and PowerEdge
- Intel
- Lenovo ThinkEdge
- Microsoft Azure Pro R



Tech and the business models around tech are really ‘embedded ideology.’ So what tech is and how it is used is a form of governance.

— Tyson Barker, German Council on Foreign Relations



Edge Trends



Hyperfine's Swoop Portable MRI acquires critical images within minutes at the bedside, and leverages embedded deep learning processes to enhance image quality.

■ Near-Real-Time Application Environments

Within the next decade, there could be as many as 50 billion devices online generating enormous amounts of data. While data centers could accommodate cloud-based solutions for that data, many of those devices will likely require real-time interaction. Enter edge computing. With the rise of immersive and interactive applications, including extended reality—and in the further future, the metaverse—more processes will be pulled onto devices to decrease or eliminate lag. Products are already in the market to address such use cases, including AWS IoT Greengrass, the platform for extending Amazon Web Services to edge devices, which was created to more easily deploy applications.

■ AI at the Edge

As ubiquitous computing expands, pulling data from countless connected

devices, the opportunity to conduct artificial intelligence–based analysis at the edge is becoming more apparent. Health care applications are able to leverage the security of edge while providing real-time information, such as new portable MRI machines that provide nearly immediate image capture with the help of built-in machine learning that ensures high-quality image production. Other industries stand to benefit as well—closed loop manufacturing systems can use AI at the edge to enhance automation and system management without significant human oversight. Open standards such as the Open Neural Network Exchange, as well as industry offerings, including Microsoft's new SynapseML open-source library, are helping to implement on-device machine learning. Other companies are expanding their offerings as well, including Lenovo's recent addition of Nvidia's GPUs (graphics processing

units) into its edge devices and the acquisition of FogHorn, a California-based developer of edge AI software for the industrial and commercial Internet of Things solutions by Johnson Controls.

■ Edge Management

As data and applications increasingly live on devices, new methods will be required to manage the data in an effective way. One such recent example is a partnership between U.K. startup Wejo and market leaders Microsoft and Palantir. Connected vehicles will generate an enormous amount of data, making latency and data storage costs a major barrier. Wejo's new ADEPT platform optimizes how the data is managed within the vehicle, filtering and processing the data at the edge, and transmitting only the most essential data to the cloud. Such systems are likely to become more common as edge management is increasingly needed.

Edge Trends



Users can leverage AWS Snowball to store data on location and later migrate the data to Amazon S3.

■ Big Tech Companies at the Edge

Nearly every major tech player now has a presence in edge computing. Amazon Web Services has edge offerings including infrastructure (such as local zones), storage, content delivery, disconnected edge (its Snow Family), robotics, machine learning, and IoT (its Greengrass solutions). IBM's edge application manager provides autonomous management for edge computing. Google's Distributed Cloud gives customers access to hundreds of network edge locations globally and supports customer-owned edge or remote locations. Facebook (now Meta) is quiet regarding edge technologies but has recently filed patent applications, including one for a "distributed, pluggable architecture for an artificial reality (AR) system" and one with a solution for "memory-based distributed database systems." Microsoft Azure Private Multi-Access Edge Compute offers various services and products, including

a service to attach and configure Kubernetes clusters, and Azure Stack Edge, a portfolio of devices. Intel boasts that it has the "most diverse edge-ready compute, memory, and storage tech"—and it just might. Its numerous offerings span edge-to-cloud, hardware, software, and ecosystem solutions.

■ Serverless Edge

Today, most data on the edge is ultimately stored in content distribution networks (CDNs), which store the data in a more localized data center that is closer to the user. While the idea of serverless edge does not yet have a distinct definition, the premise is that data will be increasingly distributed and more flexibly stored for the user. The most apt present day example is AWS' Lambda@Edge. With Lambda, code is run closer to the users, reducing latency. Customers do not have to manage infrastructure, and they pay only for the compute time they consume.

Press Release

Contact: Akira Spence, Communications Director
EPC.org | @akiras on the Matter Network

U.S. Supreme Court Rules in Favor of eSkin Data Collection

Washington, D.C., September 15, 2037: The U.S. Supreme Court rejected a case Monday that would have protected consumer data privacy rights when it ruled that employers can collect and store data drawn from employee uniforms.

The Electronic Privacy Center had closely watched the landmark case of Agnelli v. Monere after years of lobbying for individual data privacy rights. In the case, Pittsburgh factory worker Petra Hashimoto alleged that her employer, Smeeth Boot Co., and Deux Pellis, a San Francisco-based e-skin manufacturer, used her employee uniform without her permission in order to control her mood and optimize her work performance. Hashimoto did not give permission to gather the personal data used—which included health measurements and mental health assessments based on hormone levels—or to use it in any way.

The Supreme Court's conservative majority ruled that Deux Pellis had the legal right to collect and store data gathered through its technology, and that employers were within their legal rights to mandate the collection of data and use it to improve business operations.

"This is a sad day for all Americans," said Jalen Reddy, chief privacy counsel at Electronic Privacy Center, or EPC. "We assumed a federal precedent was set with the 2019 Supreme Court case of Carpenter v. United States, which ruled that the government must have a warrant before accessing a person's sensitive cellphone location data. Employers can now essentially do what they wish with your data."

EPC has for three years lobbied Congress over concerns about e-skins and dubious data collection practices. In 2031, Deux Pellis introduced its eSkin clothes, material that can harden and soften in real time to improve a wearer's posture. The eSkin also uses body chemistry to offer diet tips and share such data with digital assistants for healthier grocery shopping lists. It prescribes, orders, and delivers medications based on that body data.

The price of such clothing has dramatically dropped in the past two years—with e-skin shirts now available at Walmart for an affordable \$72. EPC voiced skepticism to Congress about the motives of the affordability of such clothing and demanded transparency about who ultimately owns the data collected.

Court documents from the Hashimoto case show the extent of consumer data collection by manufacturers and tech companies—and how it can be used. EPC has launched a petition to force companies to detail what data is collected and let employees and consumers decide how it's used. But the Court's recent decision will make that difficult. EPC expects there will be a consumer backlash against e-skins. But it's difficult to say whether that pushback will be long-lasting because so many people rely on them day-to-day.

Headquartered in Washington, D.C., EPC is an independent nonprofit research center. EPC's mission is to focus public attention on emerging privacy and related human rights issues.

The names, companies and incidents portrayed in this scenario are fictitious. No identification with actual persons (living or deceased), places, buildings, and products is intended or should be inferred.





00

01

02

03

04

05

06

07

08

09

10

11

12

13

Telecommunications & Computing

Quantum

5TH YEAR ON THE LIST

Quantum Computing



An IBM Quantum System One is now operational at the Kawasaki Business Incubation Center, serving Japan's growing quantum community in industry and scientific research.

KEY INSIGHT

Quantum computing uses properties of quantum physics—superposition and quantum entanglement—to perform computations and tasks at a much faster speed than is possible with classical computers. This nascent technology is developing quickly, and the race for first place is on.

EXAMPLES

Quantum computers can solve problems that are computationally too difficult for a classical computer, which can only process information in 1s or 0s. In quantum computing, quantum bits, or qubits, are used instead of traditional bits. Qubits leverage the quantum properties of electrons to achieve superposition—each qubit can exist in two states at the same time—as opposed to a traditional bit, which can only hold one state at a time, a 1 or a 0. Quantum entanglement, another important principle of quantum, is when two or more particles link up and then remain connected, regardless of the distance between them. Using entanglement, Chinese scientists in 2017 successfully moved data from a mountain in Tibet to a satellite in orbit, more than 870 miles away. Albert Einstein called entanglement “spooky action at a distance.” Though the principles of quantum mechanics are difficult to comprehend, the business and scientific benefits remain very real.

DISRUPTIVE IMPACT

Quantum computers, due to their ability to solve previously unsolvable problems, are being applied to the world's toughest challenges. In one instance last year, a quantum computer was used to design a more effective qubit. In health care, quantum computers will help simulate chemical reactions to speed up drug discovery and predict how proteins will fold in the body, supporting the development of protein-based therapies. In finance, quantum calculations will be used to improve forecasts and probability models, enhancing both the speed and accuracy of recommendations. Despite the many positive use cases, quantum also poses a concern for cybersecurity. Concerned that bad actors could be hacking and saving encrypted data sets now to decrypt years later when quantum computers make it possible, the U.S. government has begun an effort to create new post-quantum cryptography standards.

EMERGING PLAYERS

- Baidu
- D-Wave Systems
- Google
- Harvard-MIT Center for Ultracold Atoms
- IBM
- Intel
- Microsoft
- National Institute of Standards and Technology
- Rigetti Computing
- Samsung
- Sandbox
- Seeqc
- U.S. National Laboratories
- University of Science and Technology of China

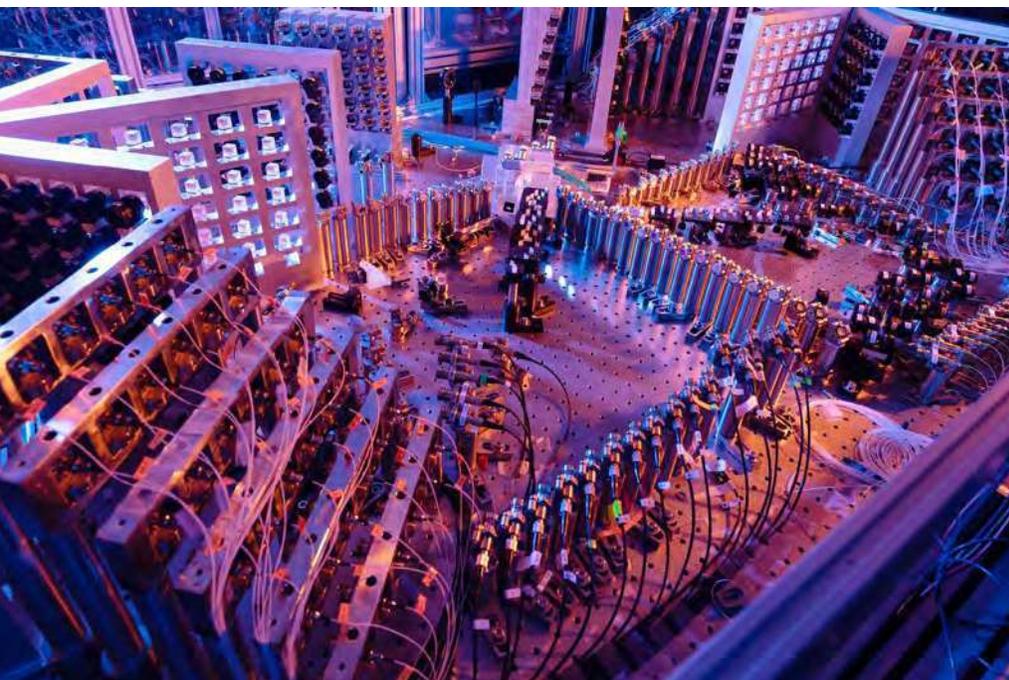


The term “quantum supremacy” was first used by John Preskill in 2011 to describe the moment when a programmable quantum device would solve a problem that cannot be solved by today’s classical computers, regardless of the usefulness of the problem.

— IEEE Computing Edge



Quantum Computing Trends



Chinese optical quantum computer Jiuzhang 2.0 can solve a problem 10^{24} faster than a classical computer.

■ Quantum Internet

It sounds simple enough: The quantum internet is the network connecting quantum connections between quantum devices. Today's classical computers connect to the internet and transmit data using a set of standardized protocols; tomorrow's quantum machines will require protocols to transmit quantum bits (qubits). Because quantum computers operate fundamentally differently than our existing machines, our current internet protocols and architectures may not be transferable. There is now a nascent but growing effort to develop the protocols that the quantum internet might require. Very early trials are underway: Quantum key distribution was demonstrated back in 2004 with a bank transfer. Quantum networks in Tokyo; Calgary, Alberta; and Los Alamos, New Mexico, are in testing, using quantum key distribution on just a few trusted nodes. A group at

Stony Brook University in New York are starting to build a quantum repeater to transmit qubits long distances.

■ Autonomous Quantum Design

Last year, researchers at the University of Science and Technology of China used a quantum algorithm to design an improved quantum bit. This new qubit, called a plasonium, is an advanced design intended to improve quantum processors. The research is significant, because complex computer chips require a large number of simulations for optimization. For years, classical computer chips have been designed using algorithms and existing computers—but the computing resources required to design advanced quantum systems aren't really possible. Tasking a quantum computer with designing improvements will accelerate insights and advancements in the space.

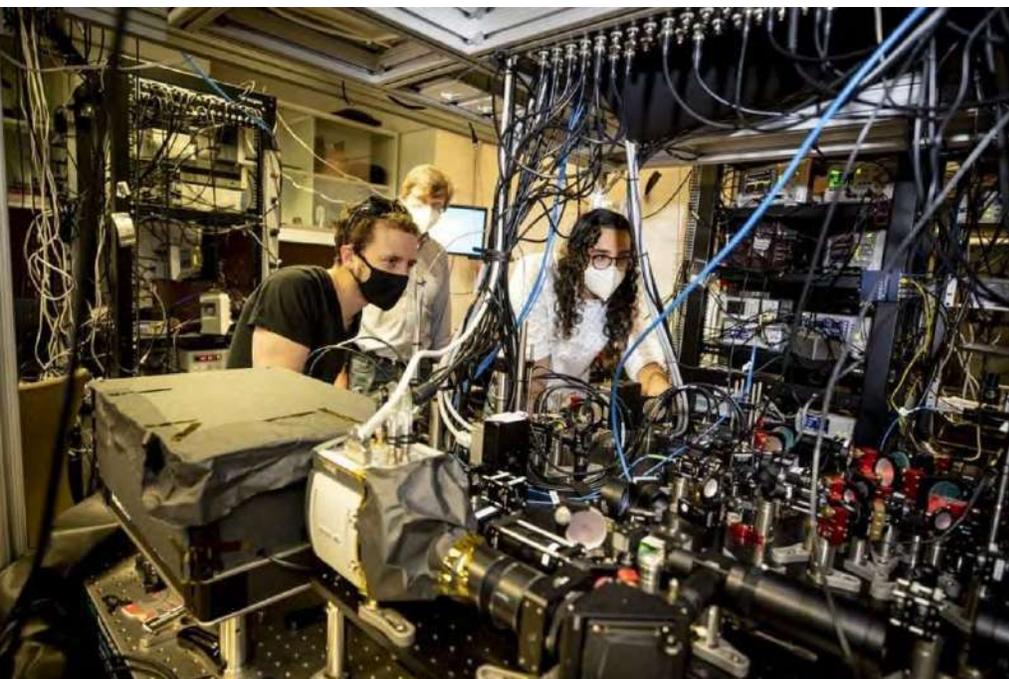
■ Self-Repairing Quantum Systems

Last July, Google's Sycamore processor detected and fixed computational errors. It was an achievement, to be sure, but the process itself introduced additional errors. That's a common issue in quantum computing: The error rates of their calculations are still high, relative to classical systems. But new research from the Maryland-based Joint Quantum Institute used trapped-ion qubits, which offered higher stability—and then used a special type of error-correction code to reduce the error rates. For now, the error correction has only succeeded on a single logical qubit—but this approach will undoubtedly evolve as more research teams design, test, and build self-repairing systems.

■ Quantum Supremacy

Quantum supremacy, a significant computational advantage allowing a

Quantum Computing Trends



(From left) Dolev Bluvstein, Mikhail Lukin, and Sepehr Ebadi at the Harvard-MIT Center for Ultracold Atoms developed a special type of quantum computer known as a programmable quantum simulator.

Image credit: Harvard University.

quantum computer to achieve a task or calculation that would be infeasible for a classical computer, has only been reached a few times. The first announced instance occurred in 2019, when researchers from University of California, Santa Barbara and Google said their 53-qubit computer, Sycamore, solved a challenging calculation in 200 seconds that would take the world's fastest classical supercomputer 10,000 years. Since late 2020, physicists at the University of Science and Technology of China announced they had built two quantum computers: Jiuzhang, a photonic quantum computer through which up to 76 photons were detected, and Zuchongzhi 2.1, a 62-qubit programmable superconducting quantum processor. Each machine is capable of carrying out Gaussian boson sampling—a baseline quantum calculation—orders of magnitude faster than even the most advanced classical supercomputer. Though not strictly quantum suprema-

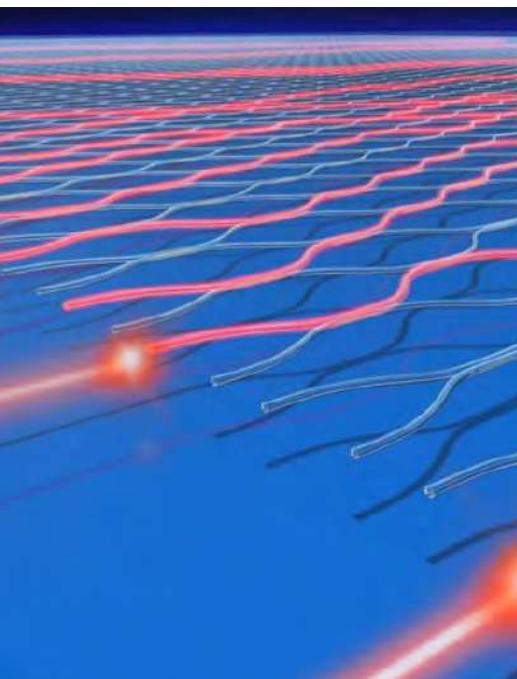
cy, in February 2021, researchers from Google and quantum computing company D-Wave Systems used a method called quantum annealing to solve a real-world problem 3 million times faster than a classical computer would take to accomplish the same task. Though that problem was previously solved by different means, this method proved that quantum annealing does have a true computational advantage.

■ Global Quantum Computing Race

The global quantum computing race is well underway. Several nations, including the U.S., France, the U.K., and China, want to become the global leader in quantum computing. Last year, several U.S.-based companies announced efforts or breakthroughs related to quantum: IBM unveiled a quantum-computing chip with 127 qubits, breaking through the three-digit qubit

milestone, and a team at Harvard-MIT Center for Ultracold Atoms announced they had developed a programmable quantum simulator capable of operating with 256 qubits. The U.S. also boasts five quantum research centers in national laboratories across the country. France has made significant investments in quantum as well, with the announcement in 2021 that the country will spend 1.8 billion euros on a national quantum strategy and launch a new quantum computing platform at the High-Performance Computing Center at the French Atomic Energy Commission in January 2022. In September 2021, the U.K. National Quantum Technologies Programme broke ground on a new National Quantum Computing Centre. Other countries, including Canada, Japan, Germany, and India, are making meaningful investment in this area, but the most noteworthy showdown is occurring between the U.S. and China. China has meaningfully funded research and

Quantum Computing Trends



The quantum computer Jiuzhang works by sending particles of light (illustrated in red) into a network of channels and then measuring the photons at the other end.

Image credit: Yihan Luo

development in quantum computing, making it a focal part of its strategic plans for the decade, and the University of Science and Technology of China has announced meaningful breakthroughs. China has more total patents for quantum technology, but the U.S. has more patents in quantum computing specifically. The United States and other countries have a vested interest in who wins this race—quantum computing holds the key to communications security and encryption—an area that the U.S. surely does not want to hand to China as an advantage.

■ Quantum Boosts for Classical Computers

While quantum computers are not yet available (or usable) at scale commercially, several players including Rigetti Computing and Seeqc are developing solutions that help companies yield

the benefits of quantum by pairing the technology with their classical computing systems. Rigetti's solution leverages the cloud to share quantum-derived solutions with its classical computer counterparts, and was implemented in Microsoft Azure last year to realize expanded benefits and efficiencies. Seeqc's solution, which Merck has invested in, is to build custom chips that layer classic microchips over a qubit array. Hybrid quantum-classical solutions are still fairly rare, but they could hold the key to more rapidly scaling the benefits of quantum computing in commercial applications.

■ Updating Post-Quantum Cryptography Standards

Quantum computing poses a serious risk to current cryptography standards, as they are able to solve much more complex problems than what classical computers can tackle today. In order to

prepare for this threat, several institutions are working to develop post-quantum cryptography standards. Currently, the five main families of post quantum algorithms are code-based, isogeny-based, hash-based, lattice-based, and multivariate-based. In early 2021, the U.S. National Institute of Standards and Technology (NIST) held a series of seminars on post-quantum cryptography and released a white paper outlining various challenges with post-quantum cryptography and planning for migration to these new standards. NIST aims to produce the first quantum-computer-proof algorithms by 2024. The European Union Agency for Cybersecurity also released a white paper last year, providing an overview of the situation and current methods being explored. The World Economic Forum's Global Future Council on Cybersecurity has also drawn up recommendations that begin to address this risk.

■ Light-Based Quantum

In late 2020, physicists at the University of Science and Technology of China announced that they had developed a photonic quantum computer named Jiuzhang, a photonic quantum computer through which up to 76 photons were detected. Jiuzhang is made from photons—particles of light, rather than superconductive materials. In December 2021, a different team of researchers at Japan's NTT the University of Tokyo; and Riken, a Japanese research institute, announced they had developed an optical fiber-coupled quantum light source, which can be used to build a full-size light-based quantum computer. Light-based quantum yields significant benefits over superconductive materials, namely by reducing quantum noise, which can disrupt the stability and reliability of the quantum computer.



Quantum computing is no longer a futuristic concept. The world has entered into the quantum decade—an era when enterprises begin to see quantum computing’s business value. This year’s unprecedented advances in hardware, software development, and services validate the technology’s momentum.

— Anna Phan, Asia Pacific Quantum Alliance Lead, IBM Quantum



How these trends impact your company



STRATEGY

The very nature of computing and connectivity is changing meaningfully, requiring leaders to create new plans that take advantage of new capabilities in order to maintain a competitive edge. While many companies are reluctant to embrace cloud storage, the need to instantly and easily access data and analyze it will soon overtake the perceived risks of off-premises storage. Executives should develop a longer-term vision for digital and data transformation, with a goal of developing a transformation plan in the near term.



INNOVATION

Connected devices will be ubiquitous over the next five years, even beyond what is seen today. As 5G and 6G emerge, improved connectivity will enable nearly everything to collect, store and transmit data. This evolution will impact nearly every business, from clothing to furniture. Chief innovation officers and their teams should evaluate the types of data their products and services naturally have access to, and develop longer-term scenarios to inform their innovation road maps.



R & D

R&D teams should pursue near-term experiments in some of these more emerging technologies, with the goal of identifying real underlying business benefits. Computing and connectivity can be difficult innovations to prove out, as their benefits are often invisible, and come across as commonplace efficiencies. Instead, R&D teams should compare and contrast the benefits of new technologies, especially edge-based capabilities and quantum experiments for more scientifically complex industry players, to identify the solutions that warrant the most investment over the coming years.



GROWTH

As we continue to build our new normal—working from anywhere, dealing with security breaches, adapting to patchwork regulation—adaptability will be key to every company's ability to thrive and succeed. There are ample opportunities for growth. Companies capable of monitoring signals and trends, modeling next-order outcomes, and actively rehearsing the future will identify new opportunities to unlock growth.

Key Questions

We recommend using this report to support your strategic foresight activity in the coming year. Every executive team should begin by asking these questions:

1

- ▶ How would increased connectivity speed and lower latency unlock new growth for our business?

- ▶ How will the expectations of our customers change when near-zero latency and lightning-fast speed become the norm?

2

- ▶ What previously “unsolvable” problems might be solved as new computing systems emerge? How would these systems make our business vulnerable?

- ▶ What new potential will be unlocked through increasingly powerful computing capabilities?

3

- ▶ How are we storing data, and are our security measures extensible for a post-quantum world?

- ▶ What new types of data could we begin to collect, and what insights might that unlock about our customers and our business?

Selected Sources

<https://www.cnet.com/tech/mobile/5gs-next-big-launch-could-make-its-improved-speed-promises-a-reality/>

<https://www.verizon.com/about/news/what-is-c-band>

<https://www.cnet.com/tech/mobile/verizon-and-at-ts-c-band-5g-upgrade-everything-you-need-to-know/>

<https://www.ericsson.com/en/blog/2021/11/persevering-with-flexibility-and-scalability-is-key-to-monetizing-enterprise-5g>

<https://www.qualcomm.com/news/onq/2022/01/04/how-snapdragon-digital-chassis-transforming-automotive-industry>

<https://www.iam-media.com/who-leads-the-5g-patent-race-2021-draws-the-end>

<https://www.nextgov.com/cio-briefing/2022/01/defense-officials-develop-5g-enabled-medical-applications-support-future-troops/360786/>

<https://www.federalregister.gov/documents/2021/07/12/2021-14656/addition-of-certain-entities-to-the-entity-list-revision-of-existing-entry-on-the-entity-list>

<https://www.semiconductors.org/taking-stock-of-chinas-semiconductor-industry/>

<https://www.wsj.com/articles/us-5g-companies-11621870061>

<https://foreignpolicy.com/2021/02/26/latin-america-united-states-china-5g-technology-war/>

<https://www.ndi.org/sites/default/files/5G%20and%20the%20Future%20Internet%20White%20Paper.pdf>

<https://www.scmp.com/tech/big-tech/article/3150473/ericssons-china-chief-remains-hopeful-prospects-country-despite>

<https://blogs.lse.ac.uk/business-review/2021/06/30/in-the-global-race-over-5g-liberalisation-and-regulatory-independence-are-key/>

https://www.softbank.jp/en/corp/news/press/sbkk/2021/20210714_01/

<https://www.ngmn.org/ngmn-news/press-release/6g-to-consider-societal-requirements-first-ngmn-6g-white-paper-presents-6g-drivers-and-vision.html>

<https://ieeexplore.ieee.org/document/9390169>

https://www.researchgate.net/publication/331728945_Six_Key_Enablers_for_Machine_Type_Communication_in_6G

<https://news.samsung.com/global/samsung-electronics-and-university-of-california-santa-barbara-demonstrate-6g-terahertz-wireless-communication-prototype>

<https://www.nokia.com/about-us/newsroom/articles/6g-explained/>

<https://www.nasdaq.com/articles/the-race-towards-6g-2021-02-18>

<https://www.politico.eu/article/6g-race-eu-united-states-china/>

<https://spectrum.ieee.org/6g-geopolitics>

<https://www.defense.gov/News/Releases/Release/Article/2650242/departments-of-defense-successfully-demonstrates-a-5g-network-for-smart-warehouse/>

<https://kyrio.com/cablelabs-certifies-first-cable-modem-with-low-latency-docsis-support/>

<https://www.cablelabs.com/converged-access-edge-controller>

<https://www.cablelabs.com/how-docsis-4-0-technology-is-enabling-the-next-generation-of-broadband>

<https://www.cablelabs.com/news/charter-and-vecima-demonstrate-long-term-hfc-network-future-with-multi-gigabit-docsis-4-0>

<https://wireless.engineering.nyu.edu/mobile-edge-and-low-latency-networking/>

<https://www.10gplatform.com/technology>

https://www.10gplatform.com/sites/default/files/TAS_10G_FINAL.pdf

<https://www.ietf.org/topics/transport/>

<https://www.cureus.com/articles/54068-teleurgery-and-robotics-an-improved-and-efficient-era>

<https://finance.yahoo.com/news/options-expands-ultra-low-latency-100100145.html>

<https://www.nature.com/articles/s41586-021-03583-3>

<https://aws.amazon.com/snowcone/?whats-new-cards.sort-by=item.additionalFields.postDateTime&whats-new-cards.sort-order=desc>

<https://www.hpe.com/us/en/insights/articles/how-the-edge-is-reshaping-healthcare-2103.html>

Selected Sources

<https://www.technologyreview.com/2021/12/14/1041961/embracing-the-promise-of-a-compute-everywhere-future/>

<https://www.techrepublic.com/article/ai-in-closed-loop-manufacturing-can-benefit-edge-computing-systems-4-things-to-consider-in-iiot/>

<https://www.infoq.com/news/2021/12/microsoft-synapseml/>

<https://www.networkworld.com/article/3647009/lenovo-expands-edge-computing-portfolio-with-ai-focused-nvidia-gpus.html>

<https://www.eenewseurope.com/news/neural-edge-platform-connected-vehicle-data-and-driverless-cars>

<https://aws.amazon.com/edge/services/>

<https://www.ibm.com/cloud/edge-application-manager>

<https://cloud.google.com/blog/topics/hybrid-cloud/announcing-google-distributed-cloud-edge-and-hosted>

<https://aws.amazon.com/lambda/edge/>

<https://dl.acm.org/doi/fullHtml/10.1145/3437378.3444367>

<https://arxiv.org/abs/2111.06563>

<https://www.newscientist.com/article/2290563-quantum-computer-helps-to-design-a-better-quantum-computer/>

<https://www.newscientist.com/article/2253089-google-performed-the-first-quantum-simulation-of-a-chemical-reaction/>

<https://www.nature.com/articles/s41534-021-00368-4>

<https://www.technologyreview.com/2021/11/03/1039171/hackers-quantum-computers-us-homeland-security-cryptography/>

<https://www.nature.com/articles/d41586-021-03476-5>

<https://scitechdaily.com/harvard-mit-quantum-computing-breakthrough-we-are-entering-a-completely-new-part-of-the-quantum-world/>

<https://science.osti.gov/Initiatives/QIS/QIS-Centers>

<https://www.euractiv.com/section/digital/news/france-opens-access-to-quantum-computing-to-researchers-start-ups/>

<https://www.scientificamerican.com/article/china-is-pulling-ahead-in-global-quantum-race-new-studies-suggest/>

<https://www.datacenterdynamics.com/en/news/microsoft-adds-rigetti-quantum-computing-to-azure-cloud/>

<https://www.hpcwire.com/off-the-wire/microsoft-to-bring-rigetti-superconducting-quantum-computers-to-azure-quantum/>

<https://nvlpubs.nist.gov/nistpubs/CSWP/NIST.CSWP.04282021.pdf>

<https://csrc.nist.gov/Projects/post-quantum-cryptography/workshops-and-timeline/round-3-seminars>

<https://www.enisa.europa.eu/publications/post-quantum-cryptography-current-state-and-quantum-mitigation>

<https://www.weforum.org/agenda/2021/09/how-corporates-can-prepare-for-quantum-computing-cyber-risks/>

<https://www.scientificamerican.com/article/light-based-quantum-computer-exceeds-fastest-classical-supercomputers/>

<https://www.science.org/doi/10.1126/science.abe8770>

<https://www.nature.com/articles/s41563-021-00953-0>



Synthetic Biology, Biotechnology & AgTech

CRISPR, gene editing, biotech, precision agriculture and automation influencing the future of business, government, food, medicine, geopolitics and society.



Table of Contents

- 545 Key Insights
- 546 **Synthetic Biology**
- 548 Synthetic Biology
- 551 **Synbio Infrastructure**
- 551 Faster Gene Synthesis
- 551 Cheaper Genome Sequencing
- 551 Completing the Human Genome
- 551 On-Demand Molecules
- 551 Microbe-Engineering as a Service
- 552 **CRISPR Technologies**
- 552 CRISPR-Based Antibiotics
- 552 CRISPR Therapies
- 552 CRISPR Diagnostics
- 553 Programmable Gene Editing Proteins
- 553 Prime Editing
- 553 Gene Vandalism
- 554 **Research Trends**
- 554 Biological Circuits
- 554 Organoids
- 554 COVID-19 Organoids
- 554 Body-on-a-Chip
- 554 Artificial Nervous Systems
- 555 Artificial Minimal Cells
- 555 Using DNA to Store Data
- 556 Cloning and Synthesizing Viruses

- 556 Living Robots
- 556 Molecular Robotics
- 556 Custom Cells
- 557 **Health Applications**
- 557 mRNA Vaccines
- 557 Genetic Screening for Pregnancy
- 557 Synthetic Wombs
- 558 Synthetic Age Reversal
- 558 Upgrading Babies
- 559 **Food Applications**
- 559 Cultured Meat
- 559 Synthesized Dairy
- 559 Precision Fermentation
- 560 Scenario: It's Grilling Season!
- 561 **Materials Applications**
- 561 Durable Biofilms
- 561 Intelligent Packaging
- 562 **Sustainability Applications**
- 562 Biosequestration
- 562 Organic Fertilizer
- 562 Greener Fashion
- 563 Rewilding
- 563 Improving Micro-Biodiversity
- 563 Engineered Mosquitoes
- 564 **Consumer Applications**
- 564 DNA-Based Marketing

- 564 Optimizing Recreational Drugs
- 564 Microbiome Test Kits
- 564 DIY Biohacking Projects
- 565 DIY Vaccines
- 566 **Society Trends**
- 566 Genetic Privacy in a Post-Pandemic World
- 566 Banning Germ Line Editing
- 566 Biobank Releases
- 566 Bias in Genetic Research
- 567 Ethics in Indigenous Genomics
- 567 A Shortage of Genome Storage
- 567 Artificial Human Genomes
- 567 International Collaborations to Advance Biology
- 569 Scenario: Creating Your Child With Wellspring
- 571 **Biotech: China Focus**
- 571 China's National DNA Drive
- 571 China's Genetically Edited Babies
- 572 Ethics Concerns
- 572 Super Animals
- 572 Unregulated Pet Cloning
- 573 **Agriculture**
- 574 AgTech
- 575 **Operations**
- 575 Ag-Fintech

- 575 Ag Marketplaces
- 575 Food Cybersecurity
- 576 **Networks and Cloud**
- 576 Farm Management Platforms
- 576 Broadband Investments
- 576 Agricultural Clouds
- 576 Farming-as-a-Service
- 578 **Data**
- 578 Precision Agriculture
- 578 Big Ag Data
- 578 Deep Learning for Food Recognition
- 579 **Sustainability**
- 579 Precision Pollination
- 579 Regenerative Agriculture
- 579 Kelp Farming
- 579 Indoor Farms
- 580 **Genetic Engineering**
- 580 Enhancing the Food Chain
- 580 CRISPR Crops
- 580 Cellular Culture Agriculture
- 580 Hybrid Animal-Plant Meats
- 580 Insect Agriculture and Bug Proteins
- 581 **Off-Planet Farming**
- 581 Space-Based Farming

- 581 Terraforming
- 583 Application
- 584 Key Questions
- 585 Selected Sources

Key Insights

- * The COVID-19 pandemic is accelerating widespread use of genetic surveillance technologies.
- * The data from DNA testing kits is being used for direct-to-consumer marketing.
- * New DNA test kits offer personalized recommendations for recreational drugs like marijuana and MDMA.
- * Synthetic biology will make aging a treatable pathology.
- * New mRNA vaccines are being developed for the flu, malaria, and even cancer.
- * You can now sequence your complete genome for \$99—which is about half the price of Apple's AirPods.
- * Scientists are using synthetic biology to discover and produce molecules on demand.
- * Scientists are in the process of building biological circuits, made of synthetic DNA, and the software that operates them.
- * Biological materials from Indigenous peoples are still missing from genetic databases, basic research, and clinical studies.
- * Fewer than 2% of people who have had their genomes sequenced are from Africa—which means an enormous number of people miss out on the benefits of genetic research.
- * Food technologists can now use genome sequencing and gene editing as part of a precision fermentation process, which results in microbes engineered for specific purposes.
- * Soon, we might be able to write megabytes of data per second on synthetic DNA that will be readable for thousands of years.
- * Research is underway to make genetic edits to embryos to correct major errors that would otherwise prevent them from being born.
- * An emerging technology called in vitro gametogenesis, or IVG, will soon allow same-sex couples to create a baby using their own genetic material without requiring donor eggs or sperm.
- * Living robots—blobs of tissue designed in labs—got a design upgrade and new capabilities. The latest versions can self-propel using tiny hairs on their surfaces. They can also operate in robot swarms to collaboratively complete a task.
- * Farms are increasingly vulnerable to cyberattacks.
- * Synthetic biology will lead to new geopolitical conflicts. The next war could be a biological one—we must prepare for the threat of bioescalation.



Synthetic Biology



The genesis machine will power humanity's great transformation, which is already underway. Soon, life will no longer be a game of chance, but the result of design, selection and choice.

— Amy Webb, writing in *The Genesis Machine*



4TH YEAR ON THE LIST

Synthetic Biology



Enviropigs are genetically engineered to excrete low levels of phosphorus.

KEY INSIGHT

Synthetic biology is a relatively new interdisciplinary field of science that combines engineering, design, and computer science with biology. Researchers design or redesign organisms on a molecular level for new purposes, making them adaptable to different environments or giving them different abilities.

EXAMPLES

We can now program biological systems like we program computers. In synthetic biology, DNA sequences are loaded into software tools—imagine a text editor for DNA code—making edits easy. After the DNA is written or edited to the researcher's satisfaction, a new DNA molecule is printed from scratch using something akin to a 3D printer. The technology for DNA synthesis (transforming digital genetic code to molecular DNA) has been improving exponentially. Today's technologies routinely print out DNA chains several thousand base pairs long that can be assembled to create new metabolic pathways for a cell, or even a cell's complete genome. These scientific innovations have fueled the rapid growth of an industry intent on making

high-value applications that include biomaterials, fuels and specialty chemicals, drugs, vaccines, and even engineered cells that function as microscale robotic machines. Progress in artificial intelligence has provided a significant boost to the field, as the better AI becomes, the more biological applications can be tested and realized. As software design tools become more powerful and DNA print and assembly technologies advance, developers can work on more complex biological creations.

DISRUPTIVE IMPACT

In the last decade, investors put \$26 billion into synbio startups, according to Built With Biology (formerly SynBioBeta), a synthetic biology industry hub. Products now underway could generate \$4 trillion by 2031. Imagine a synthetic biology app store where you could download and add new capabilities into any cell, microbe, plant, or animal. U.K. researchers have already synthesized and programmed the first *E. coli* genome from the ground up. Next, the gigabase-scale genomes of multicellular organisms—plants, animals, and our own genome—will be synthesized. We will someday have a technological foundation to cure any genetic disease in humankind, and in the process we will spark a Cambrian explosion of engineered plants and animals for uses that are hard to conceive of today but will meet the global challenges we face in feeding, clothing, housing, and caring for billions of humans. Life is becoming programmable, and synthetic biology makes a bold promise to improve human existence.

Synthetic Biology



MIT Media Lab spinout Amino Labs develops mini-lab kits with all the necessary tools and materials for anyone to start engineering microbes.

Image credit: MIT/Amino Labs

EMERGING PLAYERS

- Broad Institute
- ERS Genomics
- CRISPR Therapeutics
- Caribou Biosciences
- Editas Medicine
- Bayer
- Ginkgo Bioworks
- Twist Bioscience
- Benchling
- GenScript
- BGI Group
- Built With Biology (formerly SynBioBeta)
- JCVI

- U.S. Department of Energy Joint Genome Institute
- Synthace
- Codexis
- Zymergen
- Amyris
- Viridos (formerly Synthetic Genomics)
- Sherlock Biosciences
- Drew Endy at Stanford University
- George Church's lab at Harvard University
- Keasling Lab at the Lawrence Berkeley National Laboratory



Nature is telling us that we are on an unsustainable path, and it's time to course-correct. That does not mean abandoning technology but rather harnessing the power of biology itself to reconcile the creature comforts of human civilization with the natural world.

— Emily Leproust, Ph.D., co-founder and CEO of Twist Bioscience

The Post-Natural Age

We are transitioning from natural selection to artificial selection to intentional design facilitated by synthetic biology. The more powerful and more refined that software design tools and DNA technologies become, the more complex biological creations developers will build. We have opened the door to the post-natural age — treatment, preventing the spread of disease, and addressing global famine.



Synbio Infrastructure

■ Faster Gene Synthesis

Synthesis transforms digital genetic code into molecular DNA, allowing scientists to design and mass-produce genetic material. This is what Twist Bioscience does to form as many as 300 base pairs of DNA. Joining these snippets, or oligos, together forms genes. Both the price for oligos and time to produce them is decreasing—while the length and complexity of base pairs is increasing. It now costs an average of just nine cents per base pair. The DNA snippets produced by Twist can be ordered online and shipped to a lab within days; the synthetic DNA is then inserted into cells to create target molecules, which are the basis for new food products, fertilizers, industrial products, and medicine. One of Twist's biggest clients is Ginkgo Bioworks, a cell-engineering company valued at \$25 billion.

■ Cheaper Genome Sequencing

The first human genome cost roughly \$2.7 billion and took 13 years to complete. Today, you can sequence your genome from the comfort of your home for less than the price of a cheap TV. Nebula Genomics, a spinout from a Harvard University lab run by synthetic biologist George Church, offers to provide a person's genetic code with "medium accuracy" for \$99 or, for \$900 more, you could have 100% of your DNA decoded "with ultrahigh accuracy and ... over 300 gigabytes of DNA data," according to the company's website. Ancestry.com and 23andMe offer genotyping tests, which look only at a part of the genome, for \$99 to \$199.

■ Completing the Human Genome

The Human Genome Project—read (HGP-read)—an initiative to sequence the human genome and improve the technology and costs associated with sequencing DNA—wrapped up in 2004 and left about 8% of our DNA unexplored. In May 2021, a separate group of scientists published a preprint online describing a more complete human genome, with 3.055 billion letters across 23 human chromosomes. But there is still more work to be done: creating more genomes, so that scientists can compare different genomes to each other.

■ On-Demand Molecules

Scientists now use synthetic biology to discover and produce molecules on demand. The Defense Advanced Research Project Agency and the MIT-Broad Institute Foundry proved that new molecules can be rapidly generated for practical use. In a research challenge, teams used artificial intelligence and synthetic biology to deliver six out of the 10 requested designer molecules in just 90 days. The length of time will shorten as more efficient methods are used to discover different molecule types and produce materials as needed.

■ Microbe-Engineering as a Service

Synthetic biology is an emerging field that builds new life: replacement organs and soft tissue, as well as entirely new kinds of organisms never before seen on Earth. Zymergen, based in the Bay Area, is developing original microbes for making specialty polymers, which have applications in military equipment and electric vehicles. It raised \$400 million in its third round of funding from SoftBank Vision Fund, Goldman Sachs, Hanwha Asset Management, and others. Synthetic biologists at Ginkgo Bioworks build custom-crafted microbes for their customers. An example: designer bacteria enabling crops to fertilize themselves.

CRISPR Technologies

What Is CRISPR?

CRISPR, which stands for clustered regularly interspaced short palindromic repeats, allows scientists to edit precise positions on DNA using a bacterial enzyme. The technology is transforming cancer treatment, preventing the spread of disease, and addressing global famine.

■ CRISPR-Based Antibiotics

Antibiotic resistance is on the rise, due to overuse or incorrect application. But a new approach could enable us to tackle antibiotic-resistant infections. CRISPR can be programmed to kill certain bacterial cells that contain specific DNA. Researchers at the University of Sherbrooke demonstrated that a CRISPR-edited bacterium can be used to target an antibiotic-resistant strain of *E. coli*. When the edited bacteria were given to infected mice, they expelled 99.9% of the *E. coli* bacteria within four days. In the near future, CRISPR-edited probiotic bacteria could be used to treat bladder and skin infections.

■ CRISPR Therapies

A number of trials will test emerging CRISPR therapies in 2022. In Germany, a patient with beta thalassemia, a genetic disorder that results in low levels of

hemoglobin, had the genomes of their blood stem cells edited. Post-treatment, they have not required blood transfusions. Other patients in the trial are showing normal to near-normal hemoglobin levels. CRISPR is being used to edit T cells, a type of white blood cell essential for immune system response. T cells kill foreign or dangerous cells. In CAR-T immunotherapy, researchers genetically engineer a patient's T cells to have a receptor that recognizes the patient's cancer cells, telling the T cells to attack. The first CRISPR-based therapy trial in the U.S. was completed in February 2020, and it showed promise. Therapies for eye disease and chronic infection are also in development. One of note: a treatment for urinary tract infections. CRISPR-Cas3, combined with three bacteriophages, successfully killed the strain of *E. coli* responsible for 95% of UTIs.

■ CRISPR Diagnostics

In addition to making edits, CRISPR also allows the fast detection of pathogens by identifying sequences in their DNA or RNA. In many diagnostic systems, human pathogens are found using real-time polymerase chain reactions, which is an accurate—but time-consuming and expensive—method. Special enzymes, known as Cas enzymes, can be used to diagnose pathogens such as SARS-CoV-2, the coronavirus that causes COVID-19. Researchers at the University of California, San Diego developed a rapid diagnostic technology that detects SARS-CoV-2 using CRISPR. In early tests, SARS-CoV-2 detection took less than an hour.

CRISPR Technologies



A powerful new genetic engineering technique allows scientists to precisely cut out and replace DNA in genes.

Image credit: University of California Berkeley

■ Programmable Gene Editing Proteins

Scientists at MIT's McGovern Institute and the Broad Institute of MIT and Harvard have discovered a new class of programmable DNA modifying systems called OMEGAs (Obligate Mobile Element Guided Activity), which could move small bits of DNA throughout bacterial genomes. A new editing enzyme among a family of proteins called IscB are potential ancestors of Cas9, the enzyme often used in CRISPR-Cas9 editing. IscBs were the first proteins in an OMEGA system; their small size and ability to work in human cells mean they could be a fit for gene editing therapies.

■ Prime Editing

A gene-editing technique, which scientists call prime editing, could make the process much more precise and result in more accurate modifications. As impressive as CRISPR is, it can sometimes change the wrong genes or accidentally break apart strands of a DNA's double helix. The refinement to CRISPR affords more precision and versatility. Numerous studies advancing prime editing techniques published in 2021 will enable even more researchers to access this technology. Additionally, data shows the prime editing works in different cell types, as well as organoids and mice embryos.

■ Gene Vandalism

When the gene-editing process results in a damaged DNA helix, you have what synthetic biologist George Church calls gene vandalism. As cells try to repair the break, unintended modifications and mutations tend to occur that cannot be easily controlled and could be dangerous. Gene vandalism is on the rise as more researchers experiment with CRISPR.

Research Trends



The transplant heart was surgically removed from the donor pig before the surgery on the human patient; pig organs are considered suitable for transplant to humans because they are about the same size and shape.

Image credit: University of Maryland Medical Center

■ Biological Circuits

Scientists are in the process of building biological circuits, made of synthetic DNA, and the software that operates them. A program called DNAr, developed at the Federal University of Mato Grosso do Sul in Brazil, simulates chemical reactions, while another called DNAr-Logic enables scientists to design circuits. A high-level description of a logical circuit is then converted into a chemical-reaction network, which can be synthesized into DNA strands. By dramatically speeding up the design process for biological circuits, so could the time it takes to discover health treatments and new drugs.

■ Organoids

It's difficult and dangerous for scientists to study how living human tissue responds to viruses, medications, or other stimuli: Brain or heart tissue can't

be removed from a living person. As an alternative, scientists are creating organoids—tiny blobs grown from human stem cells that could grow into tissues. In 2008, researchers created the first cerebral organoids that provided some more understanding of brain functions. Cerebral organoids have since been used in research on autism and other diseases, such as the Zika virus. Researchers at Stanford University and the Chan Zuckerberg Biohub created human forebrain organoids (the forebrain is the part of the brain responsible for thinking, perceiving, and evaluating our surroundings). Research is underway elsewhere that would transplant bits of human brain organoids into rats, which raises both complex ethical concerns and, perhaps, fears of super-rats that process information as well as humans. Organoids aren't conscious (yet), and as experimentation progresses, scientists must develop ethical standards.

The Brainstorm Project at the National Institutes of Health will bring together scientists and ethicists to develop a set of recommendations.

■ COVID-19 Organoids

Lab-grown lung and brain tissues are being used to research the lasting effects of SARS-CoV-2, the COVID-19 virus. Miniature guts and livers are also being grown in high-security labs and infected with the virus, as are combinations of different organs to test therapies and the lasting impacts of long-haul COVID.

■ Body-on-a-Chip

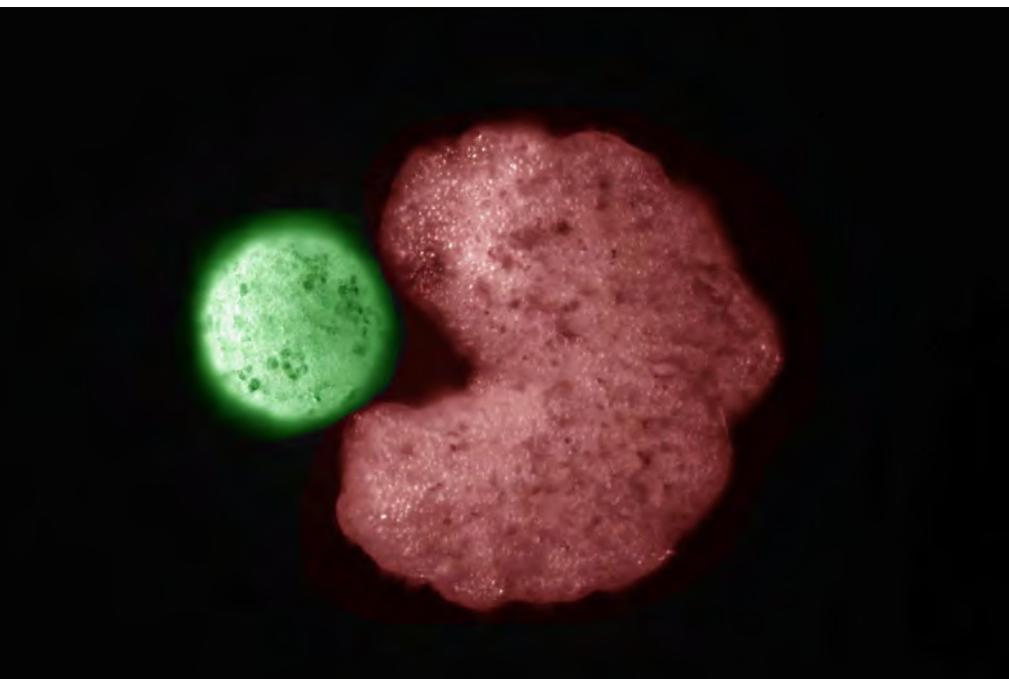
The Wake Forest Institute for Regenerative Medicine is leading a \$24 million federally funded project to develop a “body on a chip,” which will include different combinations of organoids. Picture a computer chip, but with a transparent circuit board that's con-

nected to a system pumping a blood substitute through it. Researchers can poison a mock respiratory system with new viruses, lethal chemicals, or other toxins to see how the body would react, and then test potential treatments on living human tissue without harming humans or other animals.

■ Artificial Nervous Systems

Researchers in South Korea developed an artificial nervous system that can simulate a conscious response to external stimuli. It includes an artificial neuron circuit, which acts like a brain; a photodiode that converts light into electrical signals; and a transistor that acts as a synapse. All these components are connected to a robotic hand. More hardware than wetware at the moment, this type of a system could help people with certain neurological conditions regain control of their limbs. It could eventually be worn or even embedded.

Research Trends



Living robots like this xenobot can now reproduce—and in a way not seen in plants and animals.

■ Artificial Minimal Cells

In 2010, scientist J. Craig Venter and his team announced an astonishing discovery: They could destroy the DNA of an organism called *Mycoplasma capricolum* and replace it with DNA they had written on a computer that was based on a similar bacterium, *Mycoplasma mycoides*. Venter's team named their 907-gene creature JCVI-syn1.0, or Synthia, for short. It was the first self-replicating species on the planet whose parents were, technically, computers, and the project was designed to help the team understand the basic principles of life, from the minimal cell up. In 2016, Venter's team created JCVI-syn3.0, a single-celled organism with even fewer genes—just 473—which made it the simplest life-form ever known. The organism acted in ways scientists hadn't predicted. It produced oddly shaped cells as it self-replicated. Scientists came to believe that they'd taken away too many

genes, including those responsible for normal cell division. They remixed the code once again, and in March 2021 announced a new variant, JCVI-syn3A. It still has fewer than 500 genes, but it behaves more like a normal cell. Now, researchers are working to strip down the cell even further. Last year, a new synthetic organism, *M. mycoides* JCVI-syn3B, evolved for 300 days, proving that it could still mutate.

■ Using DNA to Store Data

In 2018, scientists from Microsoft Research and the University of Washington achieved a new milestone: They discovered how to create random access memory on DNA at scale. They encoded 200 megabytes of data on human DNA—including 35 video, image, audio, and text files ranging from 29KB to 44MB. In December 2021, the team built a molecular controller and DNA writer on a chip, with a PCIe interface.

Microsoft used the system to store a version of the company's mission statement in DNA: "Empowering each person to store more!" The Intelligence Advanced Research Projects Activity, a group within the Office of the Director of National Intelligence, intends to store an exabyte of data—roughly a million terabyte-sized hard drives—in a blob of DNA. A weird branch of biological science, yes, but human computing has practical purposes: DNA could solve our future data storage problems. It's durable, too: Evolutionary scientists routinely study DNA that is thousands of years old to learn more about our human ancestors. Chinese scientists at Tianjin University stored 445KB of data in an *E. coli* cell. Twist Bioscience, a DNA storage startup, discovered how to make hyperdense, stable, affordable DNA storage. By depositing microscopic drops of nucleotides onto silicon chips, Twist's robots can create a million short

Research Trends

strands of DNA at a time. The end result will be a tiny, pill-sized container that could someday hold hundreds of terabytes of capacity. Microsoft is working on optimizing the bandwidth of writing DNA data and is advancing the chemistry of the solvents and reagents used with DNA. Soon, we might be able to write megabytes of data per second on synthetic DNA that will be readable for thousands of years.

■ Cloning and Synthesizing Viruses

Early in the pandemic, a team at the University of Bern in Switzerland published the code for a synthetic SARS-CoV-2 virus. Anyone could go online and order the required ingredients—which included the virus's genomic instructions and yeast. The journal *Nature* published the paper, which terrified national security experts concerned that \$30,000 and access to a certified

lab would allow anyone to build their own experiments. The Bern team had a different perspective: by democratizing access to the novel coronavirus, more labs could create diagnostic tests, treatments, and vaccines.

■ Living Robots

In 2020, a cluster of stem cells from an African clawed frog served as the base for a fortuitous experiment involving a supercomputer, a virtual environment, and evolutionary algorithms. Researchers created 100 generations of prototypes before they had a tiny blob of programmable tissue called a xenobot. These living robots can undulate, swim, and walk. They work collaboratively and can even self-heal. They're tiny enough to be injected into human bodies, travel around, and—maybe someday—deliver targeted medicines. In 2021, xenobots got a design upgrade and new capabilities. While before they needed the

contraction of heart muscle cells to move forward, upgraded xenobots can self-propel using tiny hairs on their surfaces. They now live longer, and they can sense what's in their environment. They can also operate in robot swarms to complete a collaborative task.

■ Molecular Robotics

Molecular robotics will someday be used on all life-forms to provide targeted therapies as well as genetic augmentation. Scientists at Harvard University's Wyss Institute discovered that both robots and our DNA can be programmed to perform tasks. Molecules can also self-assemble and react to their environments. A team of scientists at Arizona State University and Harvard created single-stranded DNA that can self-fold into origami-like shapes. It turns out that RNA can be used, too—and both can be produced inside living cells. Scientists at the California Institute of

Technology built a DNA-based version of tic-tac-toe with self-assembling DNA origami tiles. In the future, molecular robotics will offer new opportunities to advance medicine and agriculture.

■ Custom Cells

Scientists at the University of California, San Diego discovered a technique for creating cells that could send protein signals to other cells and trigger behavior—mimicking what biological cells do on their own. Artificial cells will soon have practical applications in precision medicine, or the customization of health care. But as synthetic biology evolves, the implications of future designer cells are unpredictable. New generations of cells that randomly mutate could function in ways we've not yet imagined. Programming individual cells to perform useful tasks will still take time—we're not talking about engineering synthetic humans, yet—but there are

many thought-provoking possibilities. The future of synthetic biology might, by design, include a self-destruct switch to be used after a completed task—or after we've changed our minds.

Health Applications



In 2022, mRNA vaccines will be studied for COVID-19, flu, malaria, and cancer.

■ mRNA Vaccines

As genetic material that contains instructions for making proteins, messenger RNA is revolutionizing vaccine development. Unlike traditional vaccines, which use weakened bits of a live virus or bits of dead virus, the Pfizer-BioNTech and Moderna COVID-19 vaccines instead used mRNA to inject updated code in our cells. Long before they were making COVID vaccines, both Moderna and BioNTech were researching immunotherapies for cancer. After analyzing a tissue sample from a cancerous tumor, the companies ran genetic analyses to develop custom mRNA vaccines, which encode protein-containing mutations unique to the tumor. The immune system uses those instructions to search and destroy similar cells throughout the body, which is similar to how the COVID vaccines work. BioNTech is running clinical trials for personalized vaccines

for many cancers, including ovarian cancer, breast cancer, and melanoma. Moderna is developing similar cancer vaccines. Both companies understand that the world's most powerful drug manufacturing factory on Earth may already be inside you.

■ Genetic Screening for Pregnancy

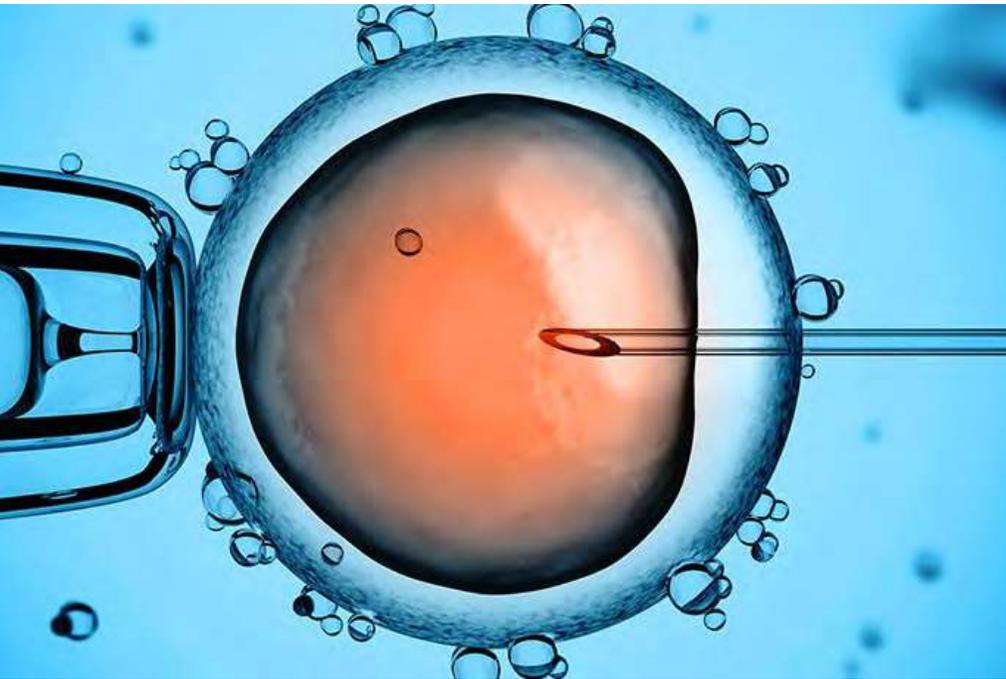
New genetic screening techniques that test embryos before implantation are making their way into fertility centers. California-based MyOme and New Jersey-based Genomic Prediction use the genetic sequences of parents, along with cells retrieved during a biopsy, to generate an embryo's entire genome. Next, they use algorithms to calculate the probabilities of certain ailments. Couples can then select the embryos they like, based on those results. While both companies are disease focused

for now, it is also possible to calculate scores and optimize for other genetic traits such as height and intelligence. Genomic Prediction provides genetic report cards to would-be parents: They can review risk assessment grades for heart attacks, certain cancers, and diabetes. They can also identify those embryos that could have extremely low intelligence as adults or become among the shortest 2% of the population.

■ Synthetic Wombs

In an experiment at Northwestern University's Feinberg School of Medicine, researchers successfully printed and implanted synthetic ovaries in mice that resulted in a successful pregnancy. Researchers at the Children's Hospital of Philadelphia created an artificial womb called a biobag and used it to successfully keep premature lambs alive and developing normally for 28 days. We are

Health Applications



Researchers are using new technologies to repair disease-causing mutations and make other edits.

still years away from synthesizing and growing a full-size organic womb—but the biobag represents an intervention that could help the thousands of premature babies born before 25 weeks each year.

■ Synthetic Age Reversal

As we age, the sequence might stay constant, but chemical changes do occur to our DNA. Observing those changes could lead to new techniques to halt or even reverse age-related disease. Columbia University researchers discovered that it might be possible to record and store information about cells as they age. The technique, a sort of biological DVR, uses the CRISPR-Cas system over a period of days. In the future, if we can quantify aging at a cellular level, we might be able to reverse it. Meanwhile, synthetic biologist George Church and a team at Harvard's Wyss Institute com-

bined into a single compound three different gene therapies related to cellular decay. The intent: reverse obesity and diabetes while also improving kidney and heart function. Remarkably, the technique seemed to work (in mice, at least).

■ Upgrading Babies

Researchers are developing a new technique that might someday enable people to upgrade their children before birth. Using algorithms to understand the tiny variations in DNA—single nucleotide polymorphisms, or SNPs—these researchers hope to make accurate gene-based predictions about an individual's future. If SNPs were read in vitro, before embryos were implanted, they could reveal whether that genetic combination had a higher probability of developing heart disease or diabetes. If an embryo was edited using CRISPR,

embryos could also be optimized with the best possible traits, given the raw genetic material. Theoretically, parents could influence myriad traits for their offspring, including hair texture, resistance to a virus such as HIV, or protection against Alzheimer's disease. This intervention, like the gene drive edit in mosquitos, would have a permanent, heritable effect. It could eradicate certain diseases passed from parents to children, and in the process improve the entire gene pool.

Food Applications



Cultured meat could make ranching a thing of the past.

■ Cultured Meat

Late in 2020, Singapore approved a local competitor to the slaughterhouse by allowing a bioreactor—a high-tech vat for growing organisms—run by a U.S. company to produce cultured chicken nuggets for its residents. In Eat Just’s bioreactors, cells taken from live chickens are mixed with a plant-based serum and grown into an edible product. This product’s popularity so far could accelerate its market entry in other countries after making it in Singapore, a highly regulated country that’s also one of the world’s most important innovation hotspots. Israel-based SuperMeat has developed a “crispy cultured chicken,” while Finless Foods, based in California, is developing cultured bluefin tuna meat, from the sought-after species now threatened by long-standing overfishing. Other companies, including Mosa Meat (in the Netherlands), Upside Foods (in California, formerly known as

Memphis Meats), and Aleph Farms (in Israel), are developing textured meats, such as steaks, that are cultivated in factory-scale labs. Unlike the existing plant-based protein meat alternatives developed by Beyond Meat and Impossible Foods, cell-based meat cultivation results in muscle tissue that is, molecularly, beef or pork.

■ Synthesized Dairy

Two California companies are offering innovative products: The Every Co. (formerly Clara Foods) serves creamy, lab-grown eggs, fish that never swam in water, and cow’s milk brewed from yeast. Perfect Day makes lab-grown “dairy” products—yogurt, cheese, and ice cream. And a nonprofit grassroots project, Real Vegan Cheese, which is also based in California, offers an open-source, DIY cheese derived from caseins (the proteins in milk) rather than harvested from animals. Casein genes

are added to yeast and other microflora to produce proteins, which are purified and transformed using plant-based fats and sugars.

■ Precision Fermentation

Food technologists can use genome sequencing and gene editing as part of a precision fermentation process, which results in microbes engineered for specific purposes. For example, feeding engineered microbes into a precisely tuned fermenter could create synthetic coconut oil or palm oil. Genetically altered microbes, which are already in use to produce plant-based meat substitutes, could soon form the basis for nondairy cheeses.

It's Grilling Season! • Far-future optimistic scenario

POLASTRI'S FINE MEATS

Omnivores, It's Grilling Season!

Our bioreactors are culturing traditional meats from starter cells for the freshest synthetic hamburgers, chicken parts and shellfish. And we've synthesized exotic creatures to offer you the boldest, most exciting flavor profiles!



- Boneless Skinless Spotted Owl Breast
- Hummingbird Skewers
- Tiger Steaks

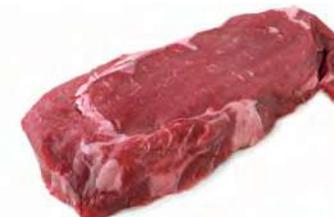
Synthetic Whole Pork Shoulder
\$16.99/ lb



Synthetic Chicken Tenders
\$12/ dozen



Synthetic Panda Bear Steak
\$27.99/ lb



Synthetic Porcupine Chops
\$19.99/ lb



Synthetic Cubed Swan Meat
\$11.99/ lb



Synthetic Whale Steaks
\$19.99/ lb



Make your selection with our virtual butcher 24 hours a day, 7 days a week
Visit our bioreactor Mon-Fri 10am - 4pm



Automated deliveries made every hour right to your door!

Materials Applications



Sustainable, intelligent packaging reduces waste and carbon emissions. Finland-based VTT develops smart packaging using sensor labels, functional bar codes, and biodegradable materials.

■ Durable Biofilms

Several companies are developing bio-based, ultra-durable hard biofilms and coatings so that chipped nails, scratched paint, and cracked screens become yesterday's problem. Zymergen developed a transparent biofilm that is thin, flexible, and durable enough to be used to transmit touch on a variety of surfaces, including smartphones, TV screens, and skin. Other possible applications include nearly invisible printed electronics that flex and move as needed. Imagine a football covered in a biofilm that could reveal, in real time, the ball's spin rate and velocity, along with the quarterback's precise hand placement.

■ Intelligent Packaging

Smart packaging will drive agricultural advances and investment. University of Minnesota researchers are developing polymers that self-destruct or “unzip” when exposed to light, heat, or acid. Saltwater Brewery designed biodegradable and edible plastic rings for six-packs of beer—so sea turtles can eat them rather than get tangled in them. Infarm created a renewable plastic that folds around objects. It uses seaweed-based agar-agar gel to grow microgreens and herbs that don't need water. Earthpac, meanwhile, makes biodegradable cutlery and trays from starch derived from potato processing wastewater.

Sustainability Applications



Synthetic biology offers new options to manage trash.

■ Biosequestration

Carbon dioxide is the undisputed culprit when it comes to climate change. But what if we could just suck it out of the air? Trees do that naturally, but with deforestation, there's not enough to make a sizable impact. Silicon Kingdom Holdings and scientists at Arizona State University manufacture artificial trees that can absorb carbon dioxide. The “leaves” are plastic-like discs that absorb CO₂ in the air and wind. When filled, the leaves drop down into the “trunk” and onward into pipes that collect the liquid CO₂ for resale to beverage companies. Columbia University has a similar project in the works. Another approach is to convert atmospheric CO₂ into carbon nanofibers for use in consumer and industrial products, such as wind turbine blades or airplanes. Chemists at George Washington University are experimenting with what they call “diamonds from the sky”—because diamonds are made from

carbon. The scientists bathe carbon dioxide in molten carbonates at 750 degrees Celsius, then introduce atmospheric air and an electrical current on nickel and steel electrodes. The carbon dioxide dissolves, and carbon nanofibers form on the steel electrode.

■ Organic Fertilizer

An artificial leaf developed at Harvard harnesses solar energy. When connected to a strain of bacteria, it converts atmospheric CO₂ and nitrogen into organic forms that can benefit living organisms. Those hungry, solar-fed bacteria essentially overeat, to the point where 30% of their body weight is excess energy—stored CO₂ and nitrogen. These microbes then get mixed into soil, and near the roots of plants they release all that nitrogen, which acts as an organic fertilizer. At that point, they also release the CO₂, yet it remains trapped underground. The result: enormous

crop yields without the environmentally poisonous side effects typically associated with chemical fertilizers.

■ Greener Fashion

The textile and clothing industry is a notorious polluter but is making steps toward more sustainable practices. Transforming cotton into fibers and textiles for clothing still relies on coal, and the process contributes 10% of global carbon emissions. Producing clothing requires a tremendous amount of water, and washing clothes made of polyester releases 500,000 tons of microfibers into the oceans each year. That's the equivalent of 50 billion plastic bottles. Roughly 85% of textiles end up in landfills annually. Plus, there are all those unwanted clothes that get discarded, by both retailers and consumers, to make way for the new season's replacements. That's enough to fill Sydney Harbor, the biggest and deepest natural harbor in

the world—every year.

So, consider if microfibers could instead be grown in a biofoundry. Bolt Threads developed a synthetic fabric called Microsilk that's engineered from spider DNA. Stella McCartney used it in a 2017 fashion show. A Japanese startup, Spiber, synthesized enough fibers to manufacture a limited-edition parka. Synthetic biology processes can transform mycelium—the fuzzy, fibrous structures that help fungi grow—into rugged material resembling leather. Whereas it takes years for a cow to mature to slaughter for its hide—during which time that cow must be fed, housed, and cared for—it takes just a few weeks for a spore to grow into mycelium leather. Hermès, famous for its highly coveted leather handbags, partnered with startup MycoWorks in 2021 to develop sustainable textiles made out of mycelium. If fibers are designed and grown, rather than harvested and

Sustainability Applications

processed, then other opportunities could open up: Bio-based pigments used to dye textiles could be edited to deposit the optimal amount of color, for example, with less water (or none at all), and be fully biodegradable.

■ Rewilding

In 2017, researchers plunged into the waters off Lizard Island on the northeastern coast of Australia with some unexpected equipment in tow—a set of underwater loudspeakers. Their destination was a coral reef that had been all but abandoned by a once-thriving population of sea life. The researchers hoped that by broadcasting the telltale sounds of a healthy reef, they might lure back some of its vital inhabitants. Remarkably, it worked. This experiment was a unique instance of rewilding, a holistic approach to conservation that focuses on restoring the natural phenomena of wilderness ecosystems,

providing connective corridors between wild spaces, and reintroducing keystone species to their natural habitats. A term coined more than 30 years ago, rewilding has gained renewed attention in the past few years as the climate crisis has grown more dire and new technologies have promised to protect and rehabilitate ecosystems.

■ Improving Micro-Biodiversity

A mass extinction event is happening right now in our guts and in the environment. The widespread use of antibiotics, along with diets rich in processed foods, have led to a staggering decline of microorganisms in wealthy nations. During the past 12,000 years of human evolution, we've shifted nature's balance—our diets are now relatively narrow, compared to our far-distant ancestors. Recently, scientists studied modern hunter-gatherer tribes in Tanzania, Peru, and Venezuela, and found their

microbiota had 50% more bacterial species than those in the West today. Unlike those tribes, we no longer hunt and eat wild flora and fauna. Those from wealthier countries now eat very little dietary fiber, a limited variety of fruits and vegetables, and only four species of livestock: sheep, poultry, cattle, and pigs. Worse, widespread use of antibiotics in farm animals—used not necessarily to prevent disease but to increase weight gain and therefore the volume of meat available—means that we're ingesting compounds that are helping to destroy our own microbiomes.

Humans are complex, composite organisms, made up of layers and layers of cells. Researchers now think that our gut microbiome is directly linked to our metabolism, our immune systems, our central nervous systems, and even the cognitive functions inside our brains. It's an inherited problem: Most of our microbiomes come to us from

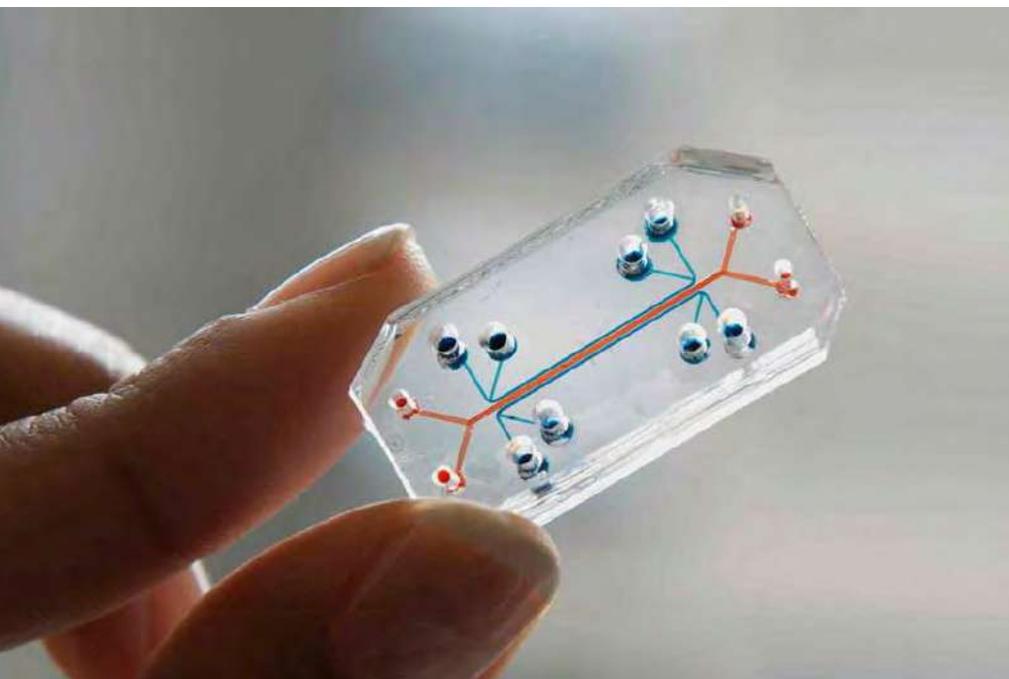
our mothers as we pass through the birth canal. A number of researchers are now looking at the future of our microbiomes. Vedanta Biosciences is making gut bacteria that can be turned into drugs and counts the Bill & Melinda Gates Foundation as one of its investors. The American Gut Project, the American Gastroenterological Association, and OpenBiome will track 4,000 patients over 10 years to learn about fecal microbiomes.

■ Engineered Mosquitoes

In May 2021, biotech company Oxitec launched a controversial field test of specially engineered mosquitoes in Florida in a move toward reducing the spread of deadly diseases such as dengue, yellow fever, and the Zika virus. Its tiny capsules contain an engineered form of the *Aedes aegypti* mosquito, called OX5034. Because only female *Aedes aegypti* bite and spread disease,

Oxitec engineered males to pass on a gene that kills female offspring before they mature. Male offspring then continue mating and passing on the altered gene. The U.S. Environmental Protection Agency says this pilot poses no human threat, while local authorities, who have been dealing with steadily growing cases of dengue fever and West Nile virus, hope that a smaller mosquito population will curb the diseases without insecticides or poisonous chemicals. Similar experiments are underway in Malaysia and Panama. As the climate crisis continues and mosquito populations spread, engineering new mutations could be a way to mitigate the challenge of disease.

Consumer Applications



Combining microfabrication techniques with modern tissue engineering, lung-on-a-chip offers a new in vitro approach to drug screening by mimicking the complicated mechanical and biochemical behaviors of a human lung.

Image credit: Wyss Institute at Harvard University.

■ DNA-Based Marketing

Some companies are offering direct-to-consumer DNA testing kits with the promise of recommendations for skin care products and foods—all based on the person's individual DNA profile. DNAnudge makes a diagnostic analysis of saliva samples and then issues users a wristband and app. When users shop, the wristband nudges them to optimal choices, while the mobile app makes DNA-based product recommendations.

■ Optimizing Recreational Drugs

When it comes to recreational drugs like marijuana, genetic factors can determine whether someone feels pleasantly relaxed or anxious and listless. New diagnostic tests promise to optimize recreational drugs for someone's unique genetic profile. Atai Life Sciences NV, based in Berlin, is researching genetics, depression, and small molecules within cells in an effort to repurpose psyc-

delics as therapies for depression and PTSD. MindMed in New York is developing a platform to help patients determine which drugs to take—therapeutics based on MDMA and DMT—depending on genetic and other data.

■ Microbiome Test Kits

The human microbiome is a mini-universe of the genetic materials living on and inside of our bodies, inherited from our gestational mothers. The number of genes in the bacteria, fungi, protozoa, and viruses that makes up our microbiomes is 200 times the number of the genes in the human genome. That microbiome weighs nearly 5 pounds, and it lives mostly in your gut and on your skin. Microbiomes differ greatly from person to person, even if you're comparing siblings who live in the same city. How well you digest lactose, how vulnerable you are to skin cancer, how well you sleep, your probability

of developing anxiety or becoming obese—all of these traits are linked to the microbiome and influenced by what you eat and drink, whether you smoke, what chemicals your body comes into contact with, and what medications you take. That data once was collected over several visits to an allergist, but today, at-home tests can determine the genetic makeup of your microbiome. Some companies will mix together special probiotic compounds to mitigate conditions or optimize the symbiotic relationship your body has with all those microorganisms.

■ DIY Biohacking Projects

Biohacking is a socio-technological movement bringing together citizen scientists, academic researchers, technologists, data scientists, and others interested in life sciences. Biohackers are developing DIY solutions for diseases and illnesses, and they're driven

Consumer Applications



In 2015, MIT scientists discovered *Ammonia-Oxidizing Bacteria* and developed consumer applications for it, including the Mother Dirt line of skin microbiome products.

by disenchantment with consolidation in the pharmaceutical industry, long regulatory processes, and slow product development. Some create novel enhancements. Openness and collaboration are valued. Biohackers share their protocols, research, and materials online, much as technologists share their code on GitHub. A group of Bay Area biohackers launched Open Insulin, a project based on the idea that insulin should be free. Diabetes affects 422 million people worldwide, and the project aims to develop the “first freely available, open organisms for insulin production that will be practical for small-scale, locally based groups to use.” Biohacking also seeks new ways to engineer food and fabric. A team of biohackers created vegan cheese from engineered yeast. They used it to develop milk proteins, which they combined with water and vegan oil to make vegan milk, and then continued on with a

more traditional cheese-making process. The recipe is open source and free. AlgiKnit uses kelp to make apparel and footwear and has developed yarn for a number of different textiles. Modified yeasts, proteins, and other bits of DNA could be hard to control, however. Novel organisms ingested or released into the world could violate the United Nations Biological Weapons Convention, even if the biohack isn’t itself intended to be a weapon. Some worry that the open-source ethos of biohacking could lead to a new class of biological weapons.

■ DIY Vaccines

Early in the pandemic, a group of citizen scientists began work on their own inoculation using a DIY approach. The Rapid Deployment Vaccine Collaborative (Radvac) includes technologists, scientists, and other researchers who believe in open-science methods.

The group, working in borrowed labs using ingredients readily found online, created a formula meant to be mixed at home and self-administered. They subsequently delivered the materials to 70 people. Radvac members, most of whom work anonymously for fear of repercussions from their universities, research labs, or funders, published a white paper detailing both the group’s research and their instructions for mixing coronavirus peptides—tiny fragments of genetic information that cannot cause COVID-19 independently. Once vaccines became available, Radvac, a 501(c)(3) nonprofit, began working on a rapid deployment platform in preparation for the next virus that hits. What about regulators? There is no regulatory framework governing the distribution of research, instructions, and supplies for DIY biohacking projects. While the U.S. Food and Drug Administration requires a stringent

set of criteria for creating and testing drugs, the FDA doesn’t technically have oversight over Radvac’s DIY vaccine kits.

Society Trends



The March 10, 1997 cover of Time Magazine featured Dolly the cloned sheep—and asked readers to consider how soon human cloning might follow.

■ Genetic Privacy in a Post-Pandemic World

The COVID-19 pandemic accelerated widespread use of infectious disease surveillance techniques, from saliva tests at airports and border crossings, to nasal swabbing at testing centers. To ease testing bottlenecks, which sometimes resulted in hours-long lines, alternative testing centers opened up: Private companies dispatched workers, who often had no medical training, to vans or small tents to administer PCR or rapid response tests. It wasn't immediately clear where the test results would be sent, or who might also gain access to the data. With the growing size and scale of third-party test results and genetic databases, anyone with the right skills could identify individuals—and we don't yet have safeguards against widespread genetic surveillance. The U.S. Department of Justice has temporarily

restricted law enforcement's ability to use third-party genetic databases to investigations of violent crimes—but the interim policy does not cover all types of investigations. Meanwhile, there are fewer restrictions on private companies buying and selling genetic data.

■ Banning Germ Line Editing

A dozen countries have banned germ line engineering in humans, though their ranks do not include the United States or China. The European Union's Convention on Human Rights and Biomedicine said tampering with the gene pool would be a crime against human dignity and human rights. But all those declarations were made before it was actually possible to precisely engineer the germ line. Now, with CRISPR, it is possible.

■ Biobank Releases

The U.K. Biobank (UKBB) made 200,000 DNA sequences available to scientists for research projects in 2021. This enormous trove of anonymized genetic data, primarily from Europeans taking part in a long-term study, includes 3 billion base pairs of human DNA. More biobank data will be made available from government-sponsored research, including the National Institutes of Health's All of Us project and the Million Veteran Program when they release their datasets in 2022. The UKBB launched a secure, cloud-based computing environment, making it easier for scientists to collaborate and integrate different types of data.

■ Bias in Genetic Research

Fewer than 2% of people who have had their genomes sequenced are from Africa. Overwhelmingly, the majority of

Society Trends

sequences come from affluent, Caucasian Americans and Europeans. This excludes an enormous number of people from the benefits of genetic research. A decade-long Three Million African Genomes project is underway to locate missing genetic variants from ancestral genomes in Africa. It would build an African biobank of clinical information and could lead to a more equitable future of genetic research.

■ Ethics in Indigenous Genomics

Biological materials from Indigenous peoples are still missing from genetic databases, basic research, and clinical studies. Here's why: Late in the 20th century, the Havasupai were grappling with an increase in diabetes. They allowed researchers from Arizona State University (ASU) to conduct a study in 1990 and collect blood samples, hoping the research would help them eradicate the disease. But then, unbeknown to

the Havasupai, the researchers changed the scope of the project to encompass genetic markers for alcoholism and various mental disorders. They went on to publish many papers in academic journals highlighting their results, which led to news stories about inbreeding and schizophrenia among tribe members. The Havasupai were, understandably, horrified and humiliated, and they filed a lawsuit against ASU in 2004. ASU eventually settled the suit in 2010, returned the blood samples to the tribe, and promised not to publish any more research. The Navajo Nation, the second-largest group of Indigenous peoples in the United States, subsequently banned all genetic sequencing, analysis, and related research on its members. Although their objections were absolutely warranted, another problem persists: The pool of genetic data in the United States doesn't include Indigenous peoples.

New initiatives could make genetic datasets and research more inclusive. The Summer Internship for Indigenous People in Genomics trains budding scientists, while the Center for the Ethics of Indigenous Genomic Research works to promote Indigenous-led research in biobanking and precision medicine. Canada and New Zealand are both working on governing frameworks and libraries to include Indigenous peoples, relying on direction from local communities.

■ A Shortage of Genome Storage

One of the fastest-growing datasets in the world comprises human genetic data. By 2025, we may be out of data storage space for human genomes, according to estimates by the University of Illinois at Urbana-Champaign. As precision medicine, CRISPR, and gene therapy technologies continue to advance, our storage needs will explode,

along with the computing power and requirements for acquiring, distributing, analyzing, encrypting, and safeguarding our genomics data. As technology increasingly intertwines with biology, inadequate storage capacity and insufficient technology workflows for storing all that data become evermore urgent issues—and the lack of planning so far becomes ever clearer. Australia's Garvan Institute of Medical Research is looking into processes and workflows to reduce the genomic data footprint.

■ Artificial Human Genomes

Genetic privacy will be increasingly difficult to safeguard—yet big genetic datasets are required to perform the kind of research that leads to new therapeutics. Scientists at the University of Tartu, Estonia, use neural networks to develop novel segments on human genomes. Because genetic data is sensitive, the hope is that an artificial human genome will

allow researchers to study DNA without infringing on anyone's privacy.

■ International Collaborations to Advance Biology

Researchers are building the first-ever comprehensive map of all 37.2 trillion human cells in the body. The effort includes 130 software engineers, mathematicians, computational scientists, biologists, clinicians, and physicists hailing from Israel, the Netherlands, Japan, the U.K., the U.S., and Sweden. Although a cell atlas has long been theorized, new biological tools and more powerful computers have turned this one-time vision into a reality. These scientists believe this mapping will give the medical community a new way of understanding how our bodies work and will help diagnose, monitor, and treat disease.



We are going from reading our genetic code to the ability to write it. That gives us the hypothetical ability to do things never contemplated before.

— J. Craig Venter, geneticist, biochemist and biotechnology pioneer





“The genetic architects at Wellspring care deeply about their patients. They didn’t overwhelm us with choices. We are confident in the upgrades we selected, and we will be forever grateful to Wellspring for helping us start our family.”

–Sawyer and Kai M.

What to Expect

Every parent(s) is assigned a personal Wellspring team who will assist you throughout your reproductive journey. Your team includes a genetic architect, a digital fertility assistant, a genetic encryption specialist, a carrier liaison, a technician, and a Wellspring concierge. For those who desire upgrades, cold storage for your embryos, or artificial incubation, your extended Wellspring team will include additional specialists.

Once your embryos have been created, your technician will conduct preimplantation screenings to ensure that your specifications have been achieved. However, sometimes changes occur. During screening, we will identify single gene defects, monogenic abnormalities, and structural rearrangements and remove those embryos as candidates.

Your digital fertility assistant and Wellspring concierge will meet with you to discuss risk factors for your strongest embryo candidates. You will select one (recommended) or two (if you are able to support twins) embryos for implantation in a carrier of your choice: you, your partner, a surrogate, or an artificial womb housed in our high-security incubation facility. If necessary or desired, your remaining embryos will be encrypted, frozen, and stored for use in future procedures.

FAQ

As you begin your journey to becoming a parent, you will undoubtedly have many questions about what traits and characteristics to select during the genetic reprogramming process. Below are answers to our clients’ most frequently asked questions.

Is the procedure to retrieve my skin cells painful?

At worst, most patients feel a minor burning sensation. After sterilizing a small patch of skin on your forearm, a technician will inject a mild local anesthetic. Once it takes effect, the technician will gently remove a bit of your skin with a precision-tooled scalpel. Stitches usually aren’t necessary, and the site typically heals within a week, without any scarring.

What traits can I select for?

During the genetic architecture phase, your digital fertility assistant will get to know you, or you and your partner(s), individually. The digital assistant will conduct interviews to learn about your worldviews, experiences, and expectations. You will also undergo a series of genetic tests to

determine heritable traits and predispositions. Once this process has been completed, we will develop a custom list of traits, and you will be invited to select from among these potentialities. They will include gender, physical attributes, cognitive dimensions, and other features.

Can I upgrade my baseline embryos?

Certain upgrades are offered to parents who meet financial qualifications. At this time, Wellspring is pleased to offer approved upgrades for memory, body mass index, bone density, lung capacity, extended pharyngeal cavity (for improved vocal resonance), mild webbing between toes (for improved performance in water sports), and engineered hyperosmia (an ultra-enhanced sense of scent).

Creating Your Child With Wellspring • Far-future neutral scenario

Is there financial assistance available to help offset the costs of upgrades?

Patients covered under the national health-care program are eligible for up to three IVG cycles and up to one new life creation. Wellspring’s world-class assistive technology will be used to create a new life within the standard genetic norms as determined by your own, or your partner(s), screenings. For example, if your cognitive norm falls within 90 to 110 intelligence quotient points, your embryos will match your score range. Upgrades that are not covered under the national healthcare program must be paid for by parent(s). Unfortunately, we do not offer financial assistance to offset the costs of upgrades.

Do military veterans automatically qualify for upgrades?

According to the current national government’s five-year schema, all military veterans are eligible for upgrades at no out-of-pocket cost. Veterans interested in upgrades must first enroll in the Mil- Gen program. Mil-Gen program participants will be assigned an additional Wellspring

liaison who will monitor the genetic architecture and screening process and select exclusive Mil-Gen upgrades for each new life. New lives created under the Mil-Gen program will be monitored until children turn eighteen, at which point they will serve their required four years in the military. After their service, they can choose a military career or transfer to an appropriate post in the government. And remember that new lives created in the Mil-Gen program are guaranteed lifetime employment and full benefits.

How can I opt in to Wellspring’s private beta upgrade programs?

Wellspring is committed to excellence. We continually scrutinize our own protocols and methodologies to exceed the exacting standards set by the national government. As assistive reproductive technology innovators, Wellspring scientists are always hard at work developing new features and upgrades. Our beta upgrade program participants meet with a specialized team that will determine, on a case-by-case basis, whether these new features and upgrades will harmonize with the desired genetic architecture of completed

embryos. Beta upgrade programs are private, opt-in opportunities between individuals and program managers. There is no charge to parents accepted into a beta upgrade program; however, the beta upgrade program should not be viewed as a workaround for parents who do not qualify for standard upgrades. Note: Mil-Gen patients are automatically entered into exclusive Mil-Gen beta upgrade programs, and such cases do not require an application.

What if I cannot find a carrier for my embryo(s)?

Wellspring’s high-security, encrypted incubation facility provides a safe alternative to in vivo pregnancy. Your artificial womb compartment is customized for your genetic profile, and compartments are monitored continuously by two digital assistants and a Wellspring Incubation Specialist. Accessing your private dashboard, you can generate an unlimited number of sonograms and ultrasounds at any time. We offer a selection of sounds—including your voice(s); white, pink, blue, or brownian noise; and music—to play at

optimal periods of developmental growth. On birth day, you and up to three family members enter the Opening Room to witness the opening of your compartment and removal of your baby by a team of automated delivery specialists. Your Wellspring concierge will then assist you with all of your new parent needs as you transition your new life into your home.



Adapted from The Genesis Machine: Our Quest to Rewrite Life in the Age of Synthetic Biology (published February 2022, PublicAffairs) by Future Today Institute CEO Amy Webb and geneticist and microbiologist Andrew Hessel.

Biotech: China Focus



China's 14th Five-Year Plan (2021 - 2025) calls for investment and applied research into synthetic biology.

■ China's National DNA Drive

Over the past decade, China has quietly created a scaled, national DNA drive to collect, sequence, and store its citizens' genetic data. DNA repositories are part of a wider panopticon, aided by the Chinese Communist Party's ambitions for artificial intelligence, to allow the government to continually surveil its constituents. In Xinjiang, the program was billed as "Physicals for All," and nearly 36 million people took part, according to China's official news agency, Xinhua. Much of the government's early DNA initiatives centered on the Uyghur population, whose data was reportedly being collected to help distinguish among China's many ethnic groups.

Chinese government researchers contributed the data of 2,143 Uyghurs to the Allele Frequency Database, an online search platform partly funded by the U.S. Department of Justice until 2018. The database, known as Alfred,

contains DNA data from more than 700 populations around the world. This sharing of data could violate scientific norms of informed consent, because it is not clear whether the Uyghurs volunteered their DNA samples to the Chinese authorities, and it's very unlikely that everyone involved knew that their DNA was being collected or understood the implications. Human rights activists say a comprehensive DNA database could be used to chase down any Uyghurs who resist conforming to the campaign, and Chinese officials have cited tracking down lawbreakers and criminals as a key benefit of the genetic studies.

China continues to collect wider swaths of genetic data from Uyghurs and other minority ethnicities, as well as from Han Chinese (who make up 91% of the country's population). Soon it will have a comprehensive, powerful genetic dataset unrivaled by any other country's. The United States, Canada, the Europe-

an Union, and the United Kingdom are debating the merits of genetic privacy. China, which collects massive amounts of information, and whose citizens seem untroubled by government surveillance, will face far less resistance to genetic studies and experimentation.

■ China's Genetically Edited Babies

Chinese researchers edited the genes of a human embryo in 2015. It was done in a petri dish, but it quickly led scientists to sound alarms about the potential of using CRISPR to modify embryos during the in vitro fertilization process. Since then, plenty of experimentation on human embryos has ensued in China. In late 2018, a team of researchers led by Dr. He Jiankui at the Southern University of Science and Technology in Shenzhen used CRISPR in conjunction with in vitro fertilization and purportedly eliminated the CCR5 gene in a pair

Biotech: China Focus



Scientist He Jiankui made a staggering announcement—that he had used CRISPR on embryos that had resulted in live births—at the second International Summit on Human Genome Editing.

of twin girls. That modification, the scientists hoped, would make the twins resistant to HIV, smallpox, and cholera throughout their lives. It would also be the first instance of genetically modified humans—despite there being no global norms and standards yet for this sort of human enhancement. The Chinese Communist Party officially permitted gene-editing experiments on embryos in 2003, as long as the embryos were only viable for 14 days or less.

■ Ethics Concerns

In 2017 a bioinformatician at KU Leuven in Belgium, Yves Moreau, noticed a red flag in a paper published in a prestigious academic journal. A study on the “male genetic landscape in China” involved a staggering 38,000 sequences for a particular genetic marker—one that is typically used in forensic investigations. The samples came from Uyghurs and other ethnic minorities in China—and

given the government’s initiatives to assimilate Uyghurs, Moreau was skeptical that the participants had given informed consent. Moreau and other academics began reviewing other papers and found similar issues in dozens of studies. The effort reveals that Chinese law enforcement have participated in some of the studies, which enable later genetic profiling. So far two papers have been retracted. At the academic journals where the studies were published, several members of editorial boards resigned to protest the lack of speed and progress in investigating flagged papers.

■ Super Animals

In 2019, a major outbreak of swine fever devastated China’s stock and killed nearly a quarter of the global pig population. Though the disease was first reported in August 2018, it took the Chinese government a long time to act. Paradoxically, the disease spread because the

Chinese government took positive steps to curb pollution. After new regulations went into effect, industrial pig farmers couldn’t upgrade their facilities fast enough, which led to farm closures and a rerouting of the pork supply. Sick pigs were shipped throughout the country, fueling the disease spread. China consumes a tremendous amount of pork, and it will take years to rebuild the swine population. Enter genome editing: Dozens of gene-editing experiments and research projects are now underway in China to develop new breeds of disease-resistant, climate-acclimating, super pigs intended for consumption. The research could have a spillover effect in other areas of agriculture and medicine, and could ultimately speed along new regulations.

■ Unregulated Pet Cloning

Sinogene, a Beijing-based commercial pet cloning company, sequenced,

cloned, and delivered a cat named Garlic for a 22-year-old businessman. Pet cloning is an unregulated business, and while Garlic wasn’t the world’s first cloned pet, he was the first for China. The United States and South Korea are other existing markets for pet cloning, but the practice hasn’t taken off there. In China, some worry, it could become more common.



00

01

02

03

04

05

06

07

08

09

10

11

12

13

Synthetic Biology, Biotechnology & AgTech

Agriculture

7TH YEAR ON THE LIST

AgTech



KEY INSIGHT

Innovations in AgTech are making it easier to collect and share data, increase crop yields, and implement sustainability measures.

A strong link exists between declining bee populations and lower crop yields due to a reduction in pollination activity.

EXAMPLES

From regenerative agriculture, to farm management software platforms to Ag-Fintech, the agricultural sector is beginning to modernize. AgTech startups are developing indoor cultivation technologies to mitigate the uncertainty brought by extreme weather events, and platforms to transition growers from analog to digital operations.

DISRUPTIVE IMPACT

In the first three quarters of 2021, 441 AgTech startups raised more than \$8.3 billion. For perspective, global AgTech companies raised a total of \$6.2 billion across 460 deals in 2020. The pandemic has highlighted technologies that look to the future, promising to sustain and improve life, while the climate crisis revealed immediate needs to reduce the volatility in our food and water supply.

EMERGING PLAYERS

- Farmers Business Network
- Indigo Agriculture
- WorldCover
- Conservis
- BeeHero
- Nutrien
- AgVend
- Raven Industries
- CropX
- Arable
- Ceres Imaging
- Gamaya
- Semios
- Fieldin

Operations



A cyberattack led to a national shortage of cream cheese in 2021.

■ Ag-Fintech

Farms have specific needs and risks—and growers must deal with high-impact, highly uncertain conditions as the climate crisis worsens. New Ag-Fintech startups are developing financial products to help growers manage risk and access capital to modernize their operations. New York-based WorldCover provides crop insurance to hedge against weather-related harvest shortfalls using satellites to monitor weather activity. Brazil-based Traive helps growers access capital by centralizing all the steps of a farmer's credit journey in one digital location. The platform uses algorithms and data to offer a layer of real-time risk assessment. In November 2021, the company announced a \$17 million Series A round, making it one of the largest-ever deals for Ag-Fintech in the region.

■ Ag Marketplaces

Growers work in an extremely low-margin business, making big capital investments risky endeavors. Enter Ag marketplaces, which are online platforms for buying, selling, leasing, and trading ag equipment, inputs, and outputs. Moving equipment around or sourcing specific crops can help growers keep their operational costs down. Farmers Business Network functions like a co-op for growers, by helping farmers buy what they need at reduced costs. Portugal-based Agri Marketplace is a digital B2B solution that connects farmers and industrial buyers. The Maano Virtual Farmers Market is an app-based e-commerce platform that connects small-holder farmers with buyers and other traders. The newest Ag marketplaces offer features akin to cryptocurrency exchange websites, where growers can get insights on grain trading and other markets.

■ Food Cybersecurity

We saw more than 50 instances of cyberattacks on the food industry in 2021. Brazil-based JBS, one of the largest meat producers, was forced to shut down several plants in Australia and the U.S. after a cyberattack—it agreed to pay hackers \$11 million in ransom fees. In October, hackers shut down Wisconsin-based Schreiber Foods, which produces the cheese slices used by most of the largest fast-food chains in the U.S. It also manufactures cream cheese—and the cyberattack happened just at the peak of cream cheese demand, leading to a nationwide shortage. We anticipate new government initiatives to address food and beverage companies' proven susceptibility to cyberattacks, as well as potentially more stringent regulatory standards to safeguard the food supply, in 2022.

Networks and Cloud



Ranveer Chandra is the principal researcher behind FarmBeats, a data-driven farming project designed to help increase farm productivity and reduce costs.

■ Farm Management Platforms

Growers can easily collect data at every level of their operations through farm management platforms and integrate that data with other service providers, including agronomists, contractors, land owners, farmhands, and other stakeholders. These cloud-based platforms give farmers better visibility into their overall operations, finances, field activities, and crop performance, and let them access their data from anywhere. Farmers will be able to make more informed decisions as these platforms increasingly feed them data from sensors attached to various equipment.

■ Broadband Investments

Modern farms need low-latency, high-speed broadband to make use of emerging technologies. The lack of internet coverage hinders the growth of rural industries and communities—a problem

we saw clearly during the pandemic, which revealed our enormous digital divides. In April 2021, Agriculture Secretary Tom Vilsack announced that the U.S. Department of Agriculture would invest \$167 million in 12 states to deploy broadband infrastructure. Similar investments are being made in other countries including China.

■ Agricultural Clouds

Microsoft launched FarmBeats, a sort of Internet of Things for farms, on its Azure marketplace. The company is testing the technology on two of its U.S. farms as part of a multiyear plan to modernize agriculture with data analytics. The system uses unlicensed, long-range TV white space spectrum to connect and capture data from solar-powered sensors, while drones gather aerial footage of crops. Machine learning algorithms mine and refine the

data, before sending analyses back to farmers with recommendations on how to tweak their resource use. This kind of cloud analytics is drawing investment and R&D, and spawning startups. Consolidation may be on the near horizon.

■ Farming-as-a-Service

The barriers to modernizing a farm's operations—lack of digital savvy and tight margins—are being overcome by new farming-as-a-service startups. Some companies, which own fleets of autonomous tractors, sell planting and other row crop services. Other startups offer equipment for lease and data management systems for an ongoing fee.

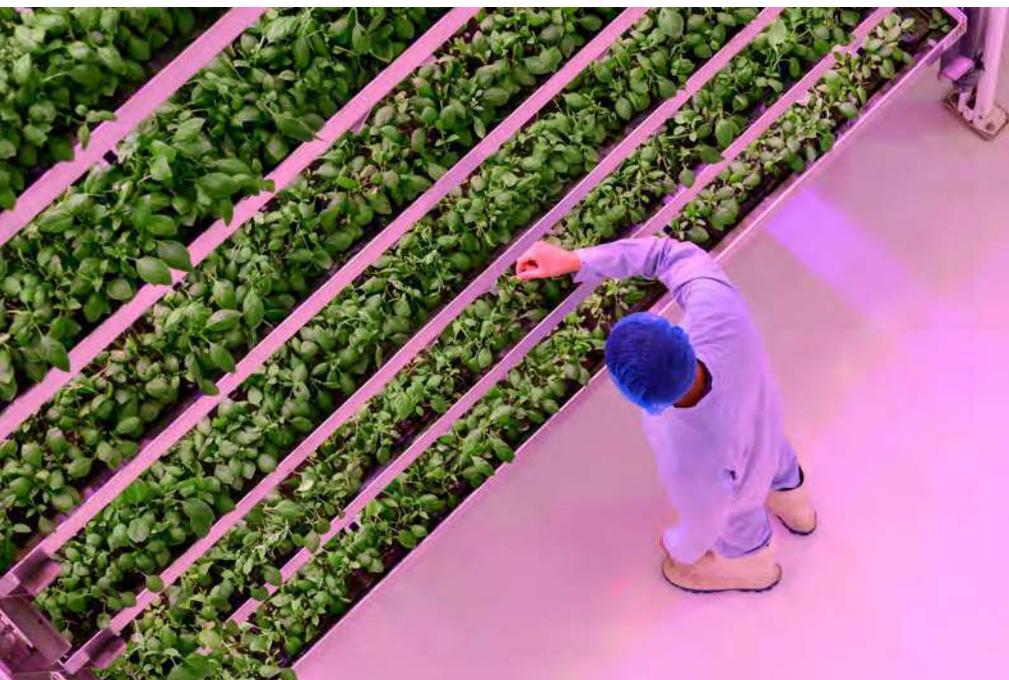


If you can write DNA, you're no longer limited to 'what is' but to what you could make.

— Drew Endy, synthetic biologist and associate professor of bioengineering at Stanford University



Data



Vertical farms reduce the uncertainty brought by extreme weather events.

■ Precision Agriculture

Precision agriculture promises to increase crop yields and profitability, while reducing the costs of watering, fertilizing, and treating crops for pests. Using sensors, algorithms, and optimization analytics, farmers can now quantify the progress of every single crop—down to a single cherry tomato hanging on a particular vine. Modern agriculture relies on efficient management and accurate predictions. University of Illinois researchers combined seasonal climate data and satellite images with the U.S. Department of Agriculture’s World Agricultural Supply and Demand Estimates to build new prediction models to help farmers predict crop yields in advance of environmental factors. South Dakota State University invested \$46 million in a precision agriculture facility and will unveil precision ag courses this year. In the near future, expect drones with

smart cameras, data mining to decipher crop blossoming and ripeness, and new analytics dashboards to help farmers make wiser decisions.

■ Big Ag Data

Researchers at the Massachusetts Institute of Technology now crunch data to come up with “plant recipes” to improve indoor food production. Using complex algorithms and sensors attached to plants inside hydroponic systems, the researchers track carbon dioxide, temperature, water, plant tissue health, and more. They analyze the data and optimize for growing the most nutritious, tastiest foods possible.

■ Deep Learning for Food Recognition

Agricultural companies, farmers, and food manufacturers could benefit from

deep learning for food recognition. Plantix, a cloud-based AI system, identifies pests and disease in crops when a farmer uploads photos of suspicious plants. Using image recognition, the system cross-references a database of various species to offer assessments of potential problems—such as lack of water or micronutrients. Automated picking systems from FFRobotics scan and “read” produce to determine ripeness. Dairy farms can monitor milk quality with SomaDetect’s optical sensors and machine learning system. Blue River Technology uses deep learning to automatically detect and spray weeds.

Sustainability

■ Precision Pollination

A decline in bee populations worldwide poses a significant threat to global food production. More than 90 species of U.S. specialty crops require pollination—and that requires healthy bee colonies. Start-ups are now using technology to help growers protect beehives from colony collapse while maximizing pollination efficiency. Los Angeles-based BeeFlow raises bees fed on processed organic molecule compounds that enhance their immune systems and teaches them to pollinate targeted flowers, while Palo Alto, California-based BeeHero uses artificial intelligence, machine learning, and sensors to collect in-hive data and stimulate greater activity during peak pollination cycles.

■ Regenerative Agriculture

Regenerative agriculture describes farming and grazing practices that rebuild soil organic matter and restore

degraded soil biodiversity. There's a clear need for this technology-led practice: Decades of using chemicals, salt-based fertilizers, carbon mining, and harsh insecticides deplete soil. Planting multiple types of crops together, rotating crops, cutting back on tilling, and reducing reliance on harsh chemicals can revitalize depleted soil, leading to improved yields, nutrient rich crops, and improved resistance to flooding and drought. In 2017, the Rodale Institute launched the Regenerative Organic Certified program to start creating an official standard. It builds on the USDA certified organic seal by adding soil health, animal welfare, and human rights requirements. General Mills announced that it would advance regenerative agriculture on 1 million acres of farmland by 2030. Meanwhile, several brands, including Patagonia, Timberland, Allbirds, Gucci, and Balenciaga, have launched efforts to promote regenerative agriculture.

■ Kelp Farming

The global supply of seaweed is in decline due to global warming. As the ocean's upper layer heats and expands, it becomes more buoyant and less likely to mix with cooler, denser water below the surface. This condition makes it difficult for marine life—and especially kelp—to thrive. Researchers are working to stimulate cooler waters using solar-powered turbines that ingest water hundreds of meters deep, and redistribute it near the warmer surface at commercial kelp farms. You may not care for the taste of seaweed, but it's a key ingredient in many diets around the world—it's also a vitally important habitat for many marine creatures. Improving and scaling offshore kelp farms could have positive ripple effects toward improving the health of the oceans and potentially cooling local air temperatures.

■ Indoor Farms

New technologies allow growers to produce plants and insects using alternative techniques, which include aquaponics, hydroponics, and vertical farming. Many countries lack the land mass or infrastructure to grow high-quality produce, so they're bringing traditional agriculture indoors and underground, using high-tech robotics, irrigation, and lighting systems to cultivate food. In the U.S., 80 Acres Farms is building a fully automated indoor farm, nearly the size of two football fields, just outside of Cincinnati. Japan has emerged as a world leader in indoor farming. Many of the country's 200 plant factories are subsidized by the government, but they thrive thanks to Japanese consumer demand for fresh, local, pesticide-free food. Near Kyoto, the Kansai Science City microfarm uses artificial intelligence and collaborative robots to raise seedlings, replant them, water them, adjust their lighting, and harvest fresh produce. In nearby Kameo-

ka, Spread uses machines and robots to cultivate plants that produce 20,000 to 30,000 lettuce heads per day. Plants mature in just 40 days before being shipped to nearby Japanese supermarkets. In California, Iron Ox's fully autonomous, hydroponic indoor farm uses two robots to plant, maintain, and harvest produce. In just a single indoor, automated acre, those two bots can produce the equivalent of 30 acres of outdoor farming. In the past, the expense of robots, artificial light, and other equipment made vertical farms difficult to scale. But that's changing as the ecosystem matures and technology improves. Today, thanks to brighter, cheaper LED light bulbs, cloud-based AI systems, and more available agricultural sensors, vertical farms can now cultivate lettuce, spinach, basil, garlic, and snow peas. They tend to deliver 10 to 20 times the total yield of conventional farms with far less waste. Vertical farming projects now scatter the globe, settling mostly in urban centers such as Baltimore and Chicago.

Genetic Engineering

■ Enhancing the Food Chain

Researchers are harnessing synthetic biology to produce better feed for animals. The startup KnipBio engineers fish feed from a microbe found on leaves, editing its genome to increase carotenoids important to fish health and using fermentation to stimulate its growth. The microbes are then pasteurized, dried, and milled. Other agricultural projects underway include synthetic organisms that can produce vast quantities of vegetable oil, and nut trees that can grow indoors using a fraction of the water these thirsty trees normally require, while also producing twice as many nuts.

■ CRISPR Crops

CRISPR promises to enhance the nutritional value of produce, increase crop yields, and extend freshness. It has increased the level of omega-3s

in plants and aided the creation of non-browning apples, drought-resistant rice, and mushrooms that can withstand jostling during transportation. (In most markets, product labels identify such products as genetically modified.) In 2021, the first CRISPR-edited tomatoes went on sale in grocery stores in Japan. The big question now is whether CRISPR-edited crops will be labeled “genetically modified organisms” and become subjected to the same regulations. The USDA has said that some edited crops—some varieties of soybeans, corn, and potatoes—don’t fall under current regulations. In 2022, regulatory agencies will review guidelines, which could have an impact on the production and sale of CRISPR crops.

■ Cellular Culture Agriculture

Cellular agriculture refers to agricultural products produced by cell cultures,

and it is key to lab-grown meat substitutes. Many U.S. grocery stores and the Mexican restaurant chain Chipotle sell Impossible meat, a beef substitute made from genetically modified yeast. Beyond Meat and Aleph Farms use pea protein and other plant material to create approximations of chicken and beef. Eclipse Foods makes a plant-based dairy ice cream base. New Wave Foods makes algae-based shrimp, and Finless Foods makes fish flesh. The clean meat movement is heading towards acellular agriculture, which doesn’t require starter cells extracted from muscle biopsies. French lawmakers banned vegetarian companies from calling their products “bacon” and “sausage.” The U.S. beef industry is petitioning to bar nonanimal products from the definition of meat. Plant-based meat sales have eclipsed \$1 billion annually. In the future, you could buy meat at a local microbrewery that “brews” meat instead of beer.

■ Hybrid Animal-Plant Meats

The cost of lab-grown meat still remains expensive. This year, we expect more new cultured-meat alternatives, made by mixing cultured beef cells and plant proteins. The Artemys Burger is a hybrid, meant to reduce the costs of cultured products and attract more consumers.

Higher Steaks, a U.K. startup, is developing blended pork products, including bacon, which includes 70% cultured pork cells mixed with plant proteins. KFC sells hybrid chicken nuggets, made of 20% cultured chicken cells and 80% plants.

■ Insect Agriculture and Bug Proteins

In some cultures, people eat bugs as part of their daily diets, but bug-based cuisine isn’t a worldwide phenomenon. That could change. The environmental-

ist case for eating crickets rather than chickens holds that raising and consuming insects produces significantly lower greenhouse gas emissions, doesn’t require extensive land and water, and inflicts less long-term damage to the planet. Moreover, bugs contain plenty of protein, fatty acids, and fiber. Only a few years ago, insect cultivation remained the domain of small, experimental startups. Recently, though, the USDA awarded \$1.45 million in research grants for bug proteins, and now the North American Coalition for Insect Agriculture estimates the market could top \$1 billion by 2023.

Off-Planet Farming



On the science fiction series *The Expanse*, based on the books by James S.A. Corey, botanists play a critical role in surviving the challenges of off-planet living.

■ Space-Based Farming

The Advanced Plant Habitat is a fully automated plant growth facility that was installed in the International Space Station in 2018. Rigged with cameras and more than 180 sensors, the data it gathers is sent back down to Earth for study. Scientists hope to learn how organic material grows differently in space. For example, germinating peppers takes an average of two weeks longer than it would on Earth due to fluid challenges in microgravity. Space agriculture is quickly becoming a multibillion-dollar industry, with startups including Square Roots, founded by Elon Musk's brother Kimbal Musk. NASA and Germany's space agency are now investing in a variety of space agricultural projects that could someday support off-planet habitats.

■ Terraforming

Terraforming—literally, “earth shaping”—is a concept from science fiction in which people re-form another planet to resemble Earth and support human life. But as humans begin serious off-planet exploration, we must develop new agricultural techniques suitable for space. Our current microbes may be key to terraforming, because they can survive such harsh environments as the Atacama Desert. Of course, we may invent entirely new life-forms using synthetic biology. To advance from theory to reality, terraforming requires a host of robots to mine for resources and build an ecosystem capable of sustaining human life, as well as hybrid-skilled researchers with backgrounds in biology, botany, agriculture, robotics, and physics.



The biggest and most durable innovations of the 21st century will be at the nexus of biology and technology. For humans, animals, plants, viruses — on Earth and off-planet.

— Amy Webb, CEO, Future Today Institute



How these trends impact your company



STRATEGY

The intersection of technology, agriculture, and biotech impacts every business, because ultimately these trends influence the future of life. Strategy officers must plan for the knock-on effects on synthetic biology and AgTech. For example, mRNA vaccines could usher in a new era of medicine, while engineered cells could upend the cosmetics industry. Cultured meats will challenge quick service and fast casual restaurants to reimagine their growth strategies. Regenerative agriculture and synbio techniques to develop fibers offer enormous potential for the fashion industry—but both require a modification to current supply chain models. First movers and fast followers could help shape the directions of their industries, which would be a long-term strategic advantage.



INNOVATION

In what ways will synthetic biology and AgTech unlock new innovation opportunities? From reimagining therapeutics to developing produce for the burgeoning space travel industry, innovation teams have a unique opportunity to envision transformational product and service ideas and map them back to long-term road maps. New consumer demand spaces will open soon, as greater advancements are made in these fields.



R & D

Thanks to the groundbreaking success of mRNA COVID-19 vaccines and the 2020 Nobel Prize awarded to the scientists behind CRISPR, the spotlight is shining brightly on biotech R&D. This is a good year to set long-term research agendas and to pursue moonshot ideas. R&D teams should work to convince executives and boards that the next few years will require research—and product development will follow.



GROWTH

The COVID pandemic and our climate crisis have shifted where and how we work, demand for health care, our willingness to use telehealth, and our familiarity with diagnostic testing. New business ecosystems are in the process of being formed to support synthetic biology and AgTech—which means that now is the time to develop strategic scenarios for long-term growth.

Key Questions

We recommend using this report to support your strategic foresight activity in the coming year. Every executive team should begin by asking these questions:

1

- ▶ In what ways will advances in synthetic biology improve our supply chain?

- ▶ Our manufacturing processes?

- ▶ Our product lines?

2

- ▶ What constitutes genetic privacy?

- ▶ Do individuals have the right to keep their genetic data private and secure from third parties?

3

- ▶ How will intellectual property and regulation enhance or impede your ability to do business in 2022?

- ▶ If the state of play changes, is your organization agile enough to adapt quickly?

Selected Sources

SEC Filings, Ginkgo Bioworks Holdings, Inc. Prospectus. September 26, 2021.

<https://innovativegenomics.org/news/crispr-clinical-trials-2021/>

<https://www.blueweaveconsulting.com/report/global-digital-farming-market-bwc19388#ReportSample/>

Marks, Renan, Daniel Vieira, Marcos Guterres, Poliana A. C. Oliveira, and Omar Vilela Neto. "DNAr-Logic: A Constructive DNA Logic Circuit Design Library in R Language for Molecular Computing," 1-6, 2019.

https://www.researchgate.net/figure/Mutation-of-Mycoplasma-mycoides-JCVI-Syn3B-resulted-in-two-strains-Syn3B-P026-and-Syn3B_tbl1_341872519

<https://www.science.org/content/article/new-artificial-nerve-could-transform-prosthetics>

<https://mcgovern.mit.edu/2021/09/09/new-programmable-gene-editing-pro>

teins-found-outside-of-crispr-systems/

<https://agfundernews.com/why-is-predicting-return-on-investment-per-field-so-hard.html>

Barton, Kenneth A., Andrew N. Binns, Antonius J. M. Matzke, and Mary-Dell Chilton. "Regeneration of Intact Tobacco Plants Containing Full Length Copies of Genetically Engineered T-DNA, and Transmission of T-DNA to R1 Progeny," *Cell* 32, no. 4 (April 1, 1983): 1033-43.

<https://iafp.confex.com/iafp/2016/webprogram/Paper11322.html>

<https://school.wakehealth.edu/Research/Institutes-and-Centers/Wake-Forest-Institute-for-Regenerative-Medicine/Research/Military-Applications/Body-on-A-Chip>

<https://www.thecattlesite.com/breeds/beef/8/belgian-blue/>

Budowle, Bruce, and Angela van Daal. "Forensically Relevant SNP Classes."

BioTechniques 44, no. 5 (April 1, 2008): 603-10.

<https://www.bloomberg.com/news/articles/2019-10-06/china-is-breeding-giant-pigs-the-size-of-polar-bears>

<https://news.harvard.edu/gazette/story/2020/06/synthetic-microbial-system-developed-to-find-objects-origin/>

<https://robbreport.com/style/accessories/hermes-vegan-mushroom-leather-1234601607/>

<https://www.businessinsider.com/elon-musk-plans-1-million-people-to-mars-by-2050-2020-1>

<https://www.nature.com/scitable/topicpage/embryo-screening-and-the-ethics-of-human-60561/>

<https://www.ncbiotech.org/news/feds-award-24m-wake-forest-lung-chip-studies>

<https://www.technologyreview.com/2015/10/19/165740/first-gene-edited-dogs-reported-in-china/>

<https://www.miamiherald.com/news/local/community/florida-keys/article249428595.html>

<http://www.fao.org/food-loss-and-food-waste/flw-data>

<https://www.foodnavigator-usa.com/Article/2020/02/11/Cell-based-meat-in-focus-In-conversation-with-Meatable-Finless-Foods-New-Age-Meats>

<https://horizon-magazine.eu/article/garbage-collecting-aqua-drones-and-jellyfish-filters-cleaner-oceans.html>

Gardner, Heather L., Karthigayini Sivaprakasam, Natalia Briones, Victoria Zismann, Nieves Perdigones, Kevin Drenner, Salvatore Facista, et al. "Canine Osteosarcoma Genome Sequencing Identifies Recurrent Mutations in DMD and the Histone Methyltransferase Gene SETD2." *Communications Biology* 2, no. 1 (July 19, 2019): 1-13.

<https://www.genomatica.com/bio-nylon-scaling-50x-to-support-global-brands/>

<https://neo.life/2018/02/get-ready-for-same-sex-reproduction/>

<https://www.cnbc.com/2021/03/01/eat-just-good-meat-sells-lab-grown-cultured-chicken-in-world-first.html>

<https://wyss.harvard.edu/news/human-organ-chips-enable-rapid-drug-repurposing-for-covid-19/>

<https://www.icvi.org/research/improving-algal-genetics-biofuels-and-biological-chemical-production>

<https://www.nytimes.com/2018/03/13/dining/fruit-vegetables-imports.html>

<https://www.reuters.com/article/us-memphis-meats-funding/lab-grown-meat-producer-memphis-meats-raises-161-million-in-funding-led-by-softbank-idUSKBN1ZL20O>

<https://www.scientificamerican.com/article/liquid-fuels-from-sunshine/>

<https://www.newyorker.com/magazine/1993/07/19/tremors-in-the-hot>

Selected Sources

house

<https://www.cms.gov/research-statistics-data-and-systems/statistics-trends-and-reports/nationalhealthexpenddata/nhe-fact-sheet>

<https://www.nationalgeographic.org/article/ocean-trash-525-trillion-pieces-and-counting-big-questions-remain/6th-grade/>

<https://www.newscientist.com/article/2245361-crops-sprayed-with-bar-coded-spores-could-help-trace-food-poisoning/>

<https://www.reuters.com/article/us-swinefever-china-epidemic-special-repo-idUSKBN20S189>

Salem, Iman, Amy Ramser, Nancy Isham, and Mahmoud A. Ghannoum. "The Gut Microbiome as a Major Regulator of the Gut-Skin Axis." *Frontiers in Microbiology* 9 (July 10, 2018).

<https://www.cnbc.com/2020/12/18/singapore-restaurant-first-ever-to-serve->

<eat-just-lab-grown-chicken.html>

Scudellari, Megan. "Self-Destructing Mosquitoes and Sterilized Rodents: The Promise of Gene Drives." *Nature* 571, no. 7764 (July 9, 2019): 160–62.

<https://www.twistbioscience.com/blog/perspectives/synthetic-biology-sustainable-food>

<https://www.zymergen.com/all-products-and-initiatives/electronics/films-hyaline/>

https://www.huffpost.com/entry/the-gut-skin-axis-the-importance-of-gut-health-for_b_5983db63e4b00833d1de2703

https://stemcells.nih.gov/info/Regenerative_Medicine/2006Chapter10.htm

<https://www.weforum.org/agenda/2020/01/fashion-industry-carbon-unsustainable-environment-pollution/>

<https://www.craftechind.com/top-3-commercial-uses-for-nylon/>

<https://www.twistbioscience.com/blog/science/top-moments-synthetic-biology-2020>

Trujillo, Cleber A., and Alysson R. Muotri. "Brain Organoids and the Study of Neurodevelopment." *Trends in Molecular Medicine* 24, no. 12 (December 2018): 982–90.

<https://www.ft.com/content/f80ea9d0-21a8-11ea-b8a1-584213ee7b2b>

<https://www.who.int/news/item/03-12-2015-who-s-first-ever-global-estimates-of-foodborne-diseases-find-children-under-5-account-for-almost-one-third-of-deaths>

<https://www.croplife.com/precision/q3-2021-agtech-venture-capital-investment-and-exit-round-up/>

<https://ucsdnews.ucsd.edu/pressrelease/researchers-develop-crispr-based-rapid-diagnostic-tool-for-sars-cov-2>

<https://www.cioreview.com/news/what-are-the-significant-agtech->

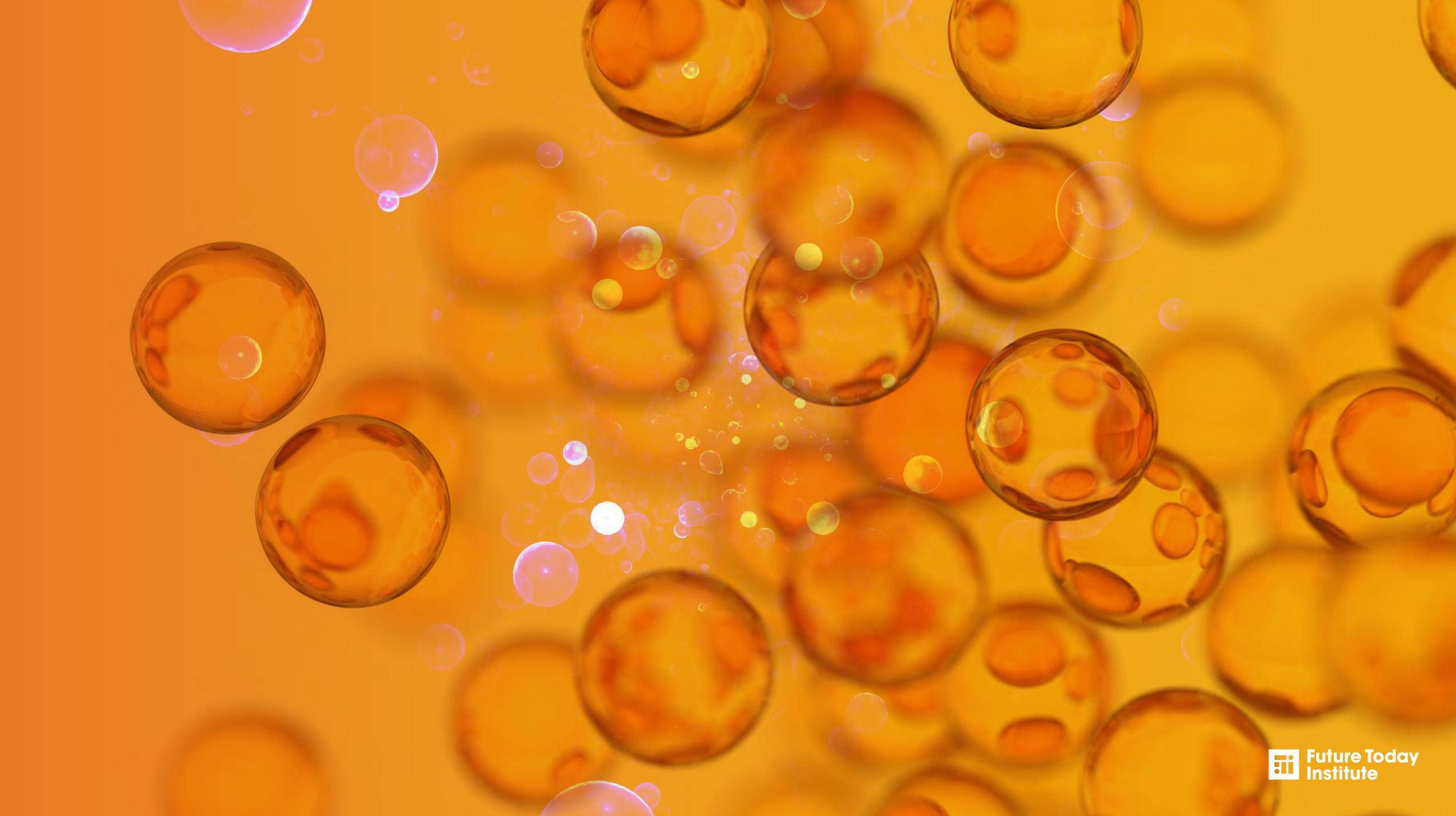
<trends-to-look-forward-to-nid-32348-cid-205.html>

Scholefield, Janine, and Patrick T. Harrison. "Prime Editing—An Update on the Field." *Gene Therapy* 28, no. 7 (August 2021): 396–401.

<https://www.bloomberg.com/news/articles/2021-12-09/that-cream-cheese-shortage-you-heard-about-cyberattacks-played-a-part>

<https://www.biorxiv.org/content/10.1101/2021.05.26.445798v1>

"Venture Capital, Private Equity, and M&A Database." PitchBook. Accessed December 22, 2021.



Climate, Energy & Space

Trends influencing the future of sustainability, energy production and consumption, and space commercialization, tourism and exploration.



Table of Contents

<p>590 Key Insights</p> <p>591 Climate and Sustainability</p> <p>593 Chief Heat Officers</p> <p>594 Climate Politics</p> <p>595 Green Stimulus Plans</p> <p>596 Large-Scale Direct Air Capture</p> <p>597 Scenario: Cloudy with a Chance of Firestorms</p> <p>598 Predicting Sea Level Rise</p> <p>599 Extreme Weather Events</p> <p>600 Human Migration Patterns Shift</p> <p>601 Plummeting Biodiversity</p> <p>602 Plastic Rain</p> <p>603 Rewilding</p> <p>604 Seasteading</p> <p>605 Managing Digital Emissions</p> <p>606 Scenario: Skin Care for the Anthropocene</p> <p>607 Anthropocene Age</p> <p>609 Green Tech Trends</p> <p>610 Ocean Iron Fertilization</p> <p>610 CO₂-Based Materials</p> <p>610 Bacterial Storage for CO₂</p> <p>610 Plastic-Eating Enzymes and Bacteria</p>	<p>611 Filtering the Ocean of Plastic</p> <p>611 Sandcastling Glaciers</p> <p>611 Reflecting Sunlight</p> <p>611 Solar Radiation Management</p> <p>612 Cloud Injections</p> <p>612 Bioengineered Trees</p> <p>612 Mycelium Revolution</p> <p>613 Ultra-White Paint</p> <p>613 Artificial Rainstorms</p> <p>614 Scenario: Growing Exotic Animals</p> <p>615 Environmental, Social and Corporate Governance (ESG) Programs</p> <p>616 Strategic Sustainability Plans</p> <p>616 Supply Chain Sustainability</p> <p>616 Shipping Industry ESGs</p> <p>617 Energy</p> <p>618 Electric Wind</p> <p>619 Building Better Batteries</p> <p>620 Fusion Power</p> <p>621 Clean Hydrogen</p> <p>623 Grid Management</p> <p>624 Charging Stations</p> <p>625 Renewable Energy</p> <p>626 Ultra-High-Voltage Direct Current and Macro Grids</p>	<p>627 Zero-Carbon Natural Gas</p> <p>628 Floating Nuclear Reactors</p> <p>629 Wireless Power Transfer</p> <p>630 Sweat Power</p> <p>631 Space</p> <p>633 Space and Off-Planet Exploration</p> <p>634 Commercializing Space</p> <p>634 Space Barons</p> <p>634 Certifying Commercial Astronauts</p> <p>634 Private Space Stations</p> <p>635 Space Tourism</p> <p>635 Galactic Ride Sharing</p> <p>635 Space Mining</p> <p>636 Space Politics</p> <p>636 Country-Level Space Initiatives</p> <p>636 Geopolitics</p> <p>636 Space Forces</p> <p>637 China's Space Ambitions</p> <p>637 Space Regulation</p> <p>638 Scenario: From Such Great Heights</p> <p>639 Space Sustainability</p> <p>639 Space Junk</p> <p>639 Space Sustainability Initiatives</p>	<p>640 Mercury Rain</p> <p>640 Monitoring Climate Change From Space</p> <p>641 Space Innovation</p> <p>641 Space Imaging</p> <p>641 Satellite Megaconstellations</p> <p>642 Self-Steering Satellites</p> <p>642 Galactic Refueling Stations</p> <p>642 Off-Planet Living</p> <p>642 Ultra-Long Space Missions</p> <p>643 Aerial and Oceanic Exploration of Other Planets</p> <p>643 Space Cuisine</p> <p>643 Scaling the Overview Effect</p> <p>644 Scenario: Beyond Earth/Beyond Human</p> <p>646 Application</p> <p>647 Key Questions</p> <p>648 Selected Sources</p>
--	---	--	--

Key Insights

- * Companies are reorganizing their workforces in response to climate change. This includes additions to the C-suite and paid time off during extreme weather conditions.
- * The lasting economic consequences of climate change are dire. Innovations from both big tech companies and startups promise to mitigate the effects, but regulators could stand in the way of progress.
- * In 2022, we will start to learn the impact of green stimulus plans in several countries around the world.
- * Several new geoengineering initiatives—including cloud injection, dumping iron into oceans, and solar radiation modification—will be tested in 2022.
- * Microplastics are everywhere.
- * Alternative power technologies, including electric wind and clean hydrogen, are gaining acceptance.
- * A new space race emerged in 2021 among some of the world's most affluent people.
- * For the first time in history, private companies will send more people to space than government agencies.
- * The era of space commercialization is here. Private space stations are under construction, and commercial astronauts will be certified in 2022.
- * This is an important year for space missions. New megaconstellations of satellites promise to beam internet connectivity from space.
- * Space junk is becoming a bigger problem as more satellites enter orbit.
- * China wants to replace the U.S. and Russia as the predominant space explorer and driver of space-related commerce and trade.



00

01

02

03

04

05

06

07

08

09

10

11

12

13

Climate, Energy & Space

Climate & Sustainability



**What you do makes a difference,
and you have to decide what kind
of difference you want to make.**

— Dr. Jane Goodall, scientist and activist



1ST YEAR ON THE LIST

Chief Heat Officers



Jane Gilbert became the first chief heat officer in 2021.

Photo courtesy Jane Gilbert

KEY INSIGHT

As global temperatures continue to rise, some cities will be disproportionately affected. To counter this trend and develop contingencies for these alarming patterns, some municipalities are establishing new positions to oversee the protection of their residents.

EXAMPLES

North America experienced the hottest June and July on record in 2021, according to the Centers for Disease Control and Prevention. Globally, July was the hottest period on record, going back 140 years. Miami-Dade County reacted to this new reality by appointing Jane Gilbert as the world's first chief heat officer. Miami-Dade Mayor Daniella Levine Cava summarized the position's purpose: to "expand, accelerate, and coordinate our efforts to protect people from heat and save lives." Other U.S. cities have created similar positions since then, including Phoenix and Los Angeles. The trend has taken hold in other parts of the world as well. Devastating fires were probably an impetus to Eleni Myrivili's appointment as the first chief heat officer in Athens, Greece. Freetown, Sierra Leone, appointed Eugénia Kargbo to the role, becoming the first nation in Africa to adopt the position.

DISRUPTIVE IMPACT

The creation of new chief heat officer positions indicates the world is finally waking up to the expansive threats of climate change. Many municipalities have programs and strategies to deal with climate hazards such as flooding but have largely overlooked heat-related threats. Chief heat officers will be tasked with raising awareness of extreme heat risks and protecting the most vulnerable communities. Both short- and long-term strategies and mitigation plans will have to be devised. It will be a challenge to find solutions that keep residents cool while also not further contributing to climate change. In 2021, Portland State University announced it was piloting a new academic program, Emergency Management and Community Resilience. The move signals that heat-mitigation strategies could start being explored at the university level, to equip a new generation with strategies that will address this existential threat.

EMERGING PLAYERS

- Phoenix City Council Office of Heat Response & Mitigation
- The City Champions for Heat Action initiative
- Extreme Heat Resilience Alliance
- Portland State University
- Miami-Dade County
- Los Angeles City Council

1ST YEAR ON THE LIST

Climate Politics



COP26 concluded with the Glasgow Climate Pact, calling 197 countries to report their progress toward more climate ambition this year, at COP27.

KEY INSIGHT

As the existential threat of climate change becomes more pronounced, world governments are implementing more regulations around the reduction of carbon emissions. Government intervention will be imperative to reverse the negative effects of climate change, especially if projections for net-zero emissions by 2050 are valid.

EXAMPLES

Governments regulating climate activities are not doing so with the same sense of urgency. Germany has aggressive greenhouse gas reduction laws, with targets of 65% reduction by 2030, 88% by 2040, neutrality by 2045, and negative emissions by 2050. These targets are even more aggressive than the European Commission's goals of 55% reduction by 2030 and net zero by 2050. Yet activists argue that France's climate laws are not ambitious enough: A French law intended to overhaul the transportation, housing, and food industries aims to reduce greenhouse gas emissions by just 40% by 2030. After reversing many climate-related regulations under previous administrations, the U.S. rejoined the Paris Agreement in 2021 and is striving for 50% emission reduction by 2030 and net zero by 2050. Climate progress hinges on China, as the country produces more carbon emissions than all developed nations combined. In 2020, China President Xi Jinping declared that the country would aim for an emissions peak by 2030 and neutrality by 2060.

DISRUPTIVE IMPACT

After a year delay due to COVID-19, the United Nations Climate Change Conference (COP26) convened in Glasgow in November 2021. World leaders made progress in many areas to help limit global warming to 1.5 degrees Celsius, as established by the Paris Agreement but overall left much to be desired. They've agreed to return this year with stronger 2030 emissions targets. Beyond addressing carbon emissions, the Glasgow Climate Pact outlined reductions for the use of coal, one of the dirtiest fossil fuels. The International Energy Agency holds that rapidly phasing out coal production is necessary if there is any hope of staying within the 1.5-degree goal. China and India caught scrutiny as they amended language in the agreement to commit to "phase down" the use of coal, rather than previous language to "phase out" coal. More aggressive action is needed to ensure the world collective the specific goal to limit global warming.

EMERGING PLAYERS

- Germany's Citizens' Assembly
- Global Assembly
- The Citizens' Convention on Climate
- Glasgow Financial Alliance for Net Zero

3RD YEAR ON THE LIST

Green Stimulus Plans



The Chicago Sunrise Movement rallies for a Green New Deal.

KEY INSIGHT

Green stimulus plans are government measures to stimulate the economy while promoting clean energy, responding to climate change, encouraging biodiversity, and protecting the environment. Government incentives offer lucrative opportunities for companies poised to enter new markets, thus creating mutually beneficial circumstances for both the environment and business.

EXAMPLES

Green stimulus plans have previously been introduced in China and Europe. While many economic stimulus packages issued after the start of the COVID-19 pandemic failed to support areas relating to climate change or biodiversity loss, spending in these areas is slowly trending upward as more countries begin to follow the lead of China and Europe. Of the \$14.9 trillion in stimulus spending by the world's leading economies, \$1.8 trillion went toward reducing pollution in energy, transportation, farming, and waste. In a break from previous administrations, the U.S. passed the Bipartisan Infrastructure Investment and Jobs Act in 2021. This law allocates \$1.2 trillion for an assortment of investments, \$108 billion of which is meant for upgrading the country's electricity grid with more environmentally friendly smart-grid technology. It also allocates \$7.5 billion for electric-vehicle chargers and \$5 billion for zero-emission buses.

DISRUPTIVE IMPACT

Job creation for green R&D investments is low relative to other industries but could still be impactful. A U.K. non-profit has released a report estimating that COVID-related job losses could reach 1 million in the country by the end of 2022 and 2 million in the next decade. The report further suggests that these outcomes could be lessened with employment opportunities in low-CO₂ sectors. Specifically, focusing on green and digital infrastructure, R&D, and energy and care could help create 1.2 million jobs within two years and 2.7 million over the next decade, offsetting the pandemic-related declines. Going even further, lucrative opportunities for businesses can result from carbon capture and removal, industrial decarbonization, water reuse, desalination, and energy storage, as long as more government agencies incentivize these initiatives moving forward.

EMERGING PLAYERS

- Green New Deal UK
- Carbon Brief
- League of Conservation Voters
- U.S. Rep. Alexandria Ocasio-Cortez (D-N.Y.)
- U.S. Sen. Edward Markey (D-Mass.)
- International Energy Agency

2ND YEAR ON THE LIST

Large-Scale Direct Air Capture



Climeworks has a direct air carbon capture plant in Iceland.

KEY INSIGHT

Direct air capture (DAC) technology pulls carbon dioxide from ambient air and is not required to capture it at the source of production, making this process more versatile than other carbon-capture methods. The CO₂ can be permanently stored in deep geological formations or used to produce new industrial products, such as fuels and chemicals.

EXAMPLES

According to the International Energy Agency, 19 direct air capture plants are operating globally. Of those, 15 are run by Climeworks, which also just brought the world's largest DAC plant online in September 2021 in Iceland. This plant captures 4 kilotons of CO₂ per year and stores it in basalt formations. In the United States, a larger DAC facility is being built by development company 1PointFive, which plans to begin operations in 2024. It is projected to capture 1 megaton of CO₂ per year.

DISRUPTIVE IMPACT

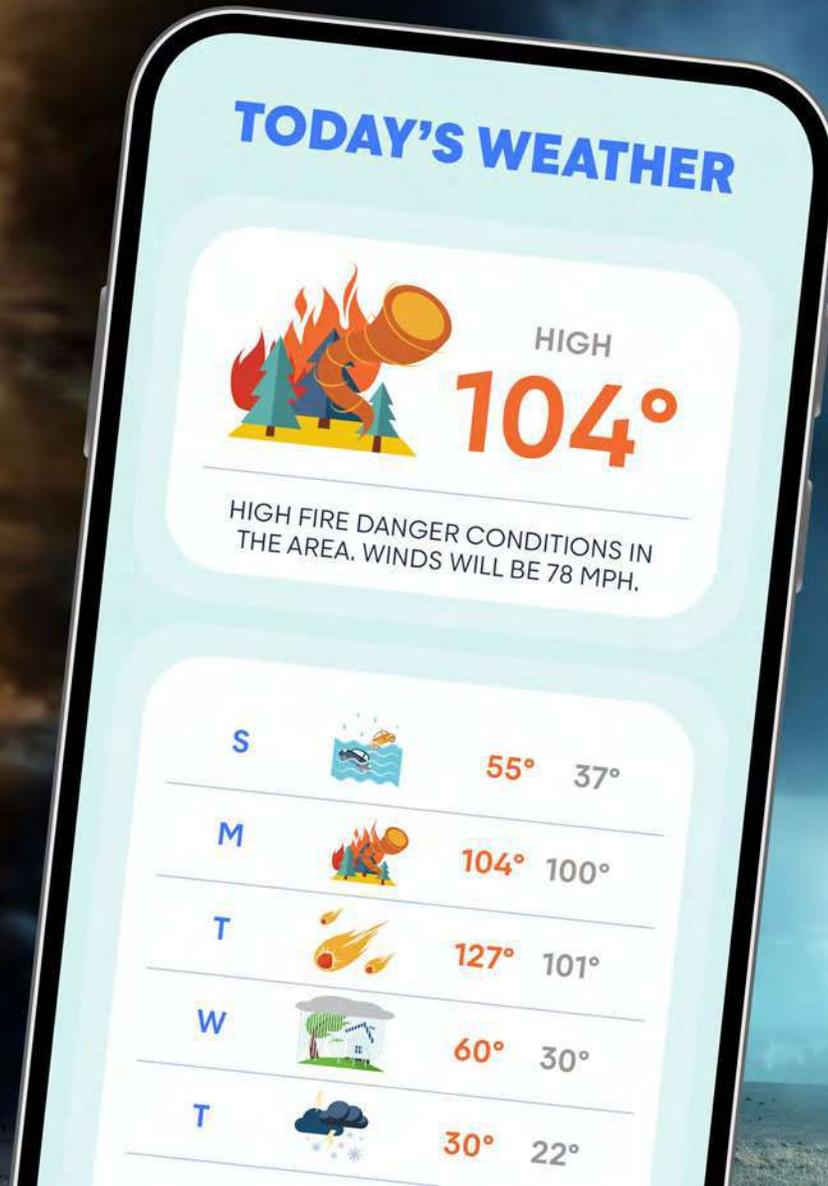
Carbon dioxide levels are higher today than they have been in the past 800,000 years. CO₂ leads to global warming, and that has a cascading effect on business and society. While it is more challenging and costly to pull CO₂ directly from the air, rather than capturing it directly at the source, the benefit of DAC is that the operation can be done anywhere, while not requiring the identification and cessation of polluting activities. The viability of direct air capture will increase as organizations move to bring the cost of technological carbon removal to under \$100 per ton. Companies and organizations such as Microsoft, Stripe, Swiss Re, and the band Coldplay are already turning to DAC to offset their carbon activities.

EMERGING PLAYERS

- SoCalGas
- 1PointFive
- Oxy Low Carbon Ventures
- Carbon Engineering
- Occidental Petroleum
- Bill Gates
- Microsoft
- Storegga
- Climeworks

Cloudy with a Chance of Firenados

By 2030, weather apps no longer limit their forecasts to temperature, rain, sleet, snow, and wind. These apps also show when extreme weather is likely, whether it's a firenado, plastic rain, smoke clouds with orange skies, extreme flooding or major drought.



4TH YEAR ON THE LIST

Predicting Sea Level Rise



Glacier melt has accounted for 21% of sea-level rise dating back two decades.

KEY INSIGHT

It is becoming easier to understand how ice sheets and sea levels change over time. While sea-level rise will result in less habitable land, not all outcomes are predictable. In the years ahead, there will be more focus on trying to measure, interpret, and intervene in the rate of change.

EXAMPLES

As the planet warms at an increasing rate, 2021 brought deadly floods to Germany and Nigeria, and concerning melting incidents to the Arctic. A recent study by the European Geosciences Union proposed a new method to quantify the rise of sea levels: By comparing historical data with the sea's sensitivity to warming, the study found that the Intergovernmental Panel on Climate Change's projection of 39 inches of sea level rise by the end of the century to be conservative. The figures could be as much as 10 inches higher per century, according to the study. To underscore this global threat, an additional study by Nature Communications suggested that by 2100, a 1-meter sea-level rise with zero population growth will result in 410 million people living on land less than 2 meters above sea level.

DISRUPTIVE IMPACT

It is difficult to overstate how significantly rising sea levels will impact human and animal migration, and the global supply of food. Many of the scientists studying the impact of rising seas are focusing on long-term scenarios, but Aljosja Hooijer, a specialist water resources expert for Deltares, emphasizes that sea-level rise is already happening in parts of the world, mostly in the tropics, Southeast Asia, and Nigeria. While developed countries such as the U.S. regularly run remote sensing called LiDAR to keep track of sea-level change and plan to implement walls and barriers to protect coastlines. The most vulnerable countries in the Global South will more likely have to rely on effective evacuation and increased humanitarian aid.

EMERGING PLAYERS

- Deltares
- European Geosciences Union
- Climate Central
- Princeton University
- The Potsdam Institute for Climate Impact Research

4TH YEAR ON THE LIST

Extreme Weather Events



The hottest July on record in the United States led to hundreds of fires that burned more than 1 million acres.

KEY INSIGHT

An extreme weather event is one that falls outside the statistical norms of typical fluctuations in weather patterns. Such events became a more frequent and pronounced worldwide phenomenon in 2017, and we have been experiencing them since.

EXAMPLES

The past decade was the warmest on record worldwide. Since 1901, the average surface temperature rose an average rate of 0.17 degrees Fahrenheit per decade. In 2021, North America experienced the hottest June in 127 years, averaging 4.2 degrees above normal and delivering heat waves that broke records across the Southwest and West, the Pacific Northwest, and Western Canada. The U.S. also experienced more than eight weather and climate disasters in just the first six months of 2021—costing taxpayers more than \$1 billion per event. Droughts caused devastating wildfires: In the first seven months of 2021, 3 million acres were consumed by fire. In other parts of the world, July also brought destruction. Storms dropping 15 centimeters of rain in 24 hours caused flooding and massive landslides in Europe and killed 196 people in Germany and Belgium. Estimates suggest that these floods were nine times more likely because of climate change.

DISRUPTIVE IMPACT

Extreme weather is the new normal. Tropical storms move more slowly than they did 40 years ago, lingering longer and causing more damage. A leaked draft report from the Intergovernmental Panel on Climate Change, obtained by a French news agency, issued a stark warning: “The worst is yet to come.” The report suggests the future will be fraught with more mass extinction, lengthier fire seasons, food system losses, ecosystem collapses, further rising sea levels, increased spread of disease, and dangerously high temperatures. The report also implies that those least responsible for climate change will suffer inordinately more. To make matters worse, current trends project that we are headed toward 3 degrees Celsius above mid-19th century levels at best, despite the Paris Agreement’s 2015 vow to not exceed 1.5 degrees Celsius.

EMERGING PLAYERS

- National Centers for Environmental Information
- Intergovernmental Panel on Climate Change
- Chooch Intelligence Technologies
- DroneSeed
- Jupiter
- Ladera Tech
- Severe Weather Information Centre

5TH YEAR ON THE LIST

Human Migration Patterns Shift



In February 2021, East Jakarta, Indonesia, was hit with heavy rain and flooding that inundated neighborhoods.

© UNICEF/UN0421878/Wilander

KEY INSIGHT

There's no official designation for "climate change refugees," and as more people become displaced worldwide, climate migrants will face added complications. By 2050, as many as 1 billion people could be displaced. Even in the most optimistic scenarios, tens to hundreds of millions could be forced to leave their homes.

EXAMPLES

In a six-month span from September 2020 to February 2021, 10.3 million people were displaced due to climate change-driven events, such as flooding and droughts. A majority of these impacted individuals were in Asia. In contrast, only 2.3 million were displaced due to conflict in the same span of time. According to the Children's Climate Risk Index, 1 billion children reside in areas that are considered extremely high risk from the impacts of climate change. A more conservative report by the World Bank projected that 200 million people could be displaced because of climate change by 2050, while The Institute for Economics and Peace put that number at up to 1 billion.

DISRUPTIVE IMPACT

Throughout the world, climate change is becoming a national security issue as monsoons, droughts, and scorching heat drive millions of people away from their homes in search of more hospitable environments. From Nicaragua to South Sudan, climate change is already creating shortages in food, potable water, land, and other natural resources. Because the United Nations refugee agency still does not qualify climate migrants as refugees, climate migrants face complications finding recourse from these life-altering disasters. To further exacerbate matters, additional conflict can arise between climate migrants and their host communities as they compete over resources. Additionally, millions of individuals displaced by climate change become subjected to modern-day slavery, debt bondage, prostitution, or forced marriages. This raises the stakes if world powers do not collectively work toward drastically cutting greenhouse gas emissions and increasing education, training, and jobs for migrants.

EMERGING PLAYERS

- The Institute for Economics and Peace
- Refugees International
- UNICEF
- Refugee Investment Network
- Startup Refugees

2ND YEAR ON THE LIST

Plummeting Biodiversity



Human activity such as air pollution is leading to unprecedented levels of biodiversity loss.

KEY INSIGHT

We're living through a strange contradiction: We may seem to be in close contact with an ever-increasing number of wild animals and novel pathogens, but in reality, our planet's biodiversity has plummeted. This is not only a planetary injustice, it puts humans' survival at risk.

EXAMPLES

The human race accounts for less than 0.01% of the biomass on Earth. Yet human activity is at least partly responsible for vertebrate species declining by an estimated 70% on average in the past half century. The main ways humans do this are by destroying habitats with resource extraction, mass consuming natural resources, and polluting. These continued habits could lead to the extinction of one-third to one-half of all species by the turn of the century. The U.N.'s Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services projects that 1 million animal and plant species are at risk of destruction, including 40% of all amphibian species, 33% of corals, and 10% of insects.

DISRUPTIVE IMPACT

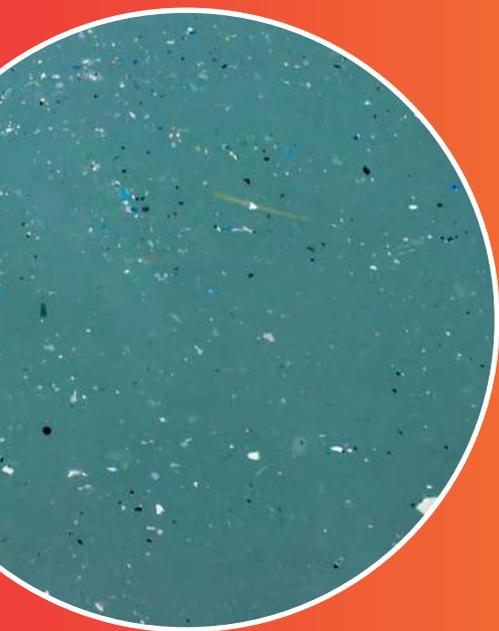
The recent collapse of insect populations in Puerto Rico and Germany had a cascading effect: Pollinators disappeared, plants failed to germinate and grow, and wildlife lost their habitats and food sources. Seemingly insignificant changes in ecosystems actually have a disproportionately severe impact. While species are disappearing at alarming rates globally, consensus is emerging that this may not be true on the local level. Some species and ecosystems are crashing, yet others are affected at slower rates, and some are even remaining steady or thriving. This does not negate the problem, however. Thriving ecosystems rely on new species moving in when older ones leave or die out. Even small ecosystem changes at the local level have significant importance, as they provide food, fresh water, fuel, and pollination for many organisms and even humans.

EMERGING PLAYERS

- International Union for Conservation of Nature and Natural Resources' Red List
- Yale University Office of Sustainability
- The Convention on Biological Diversity

2ND YEAR ON THE LIST

Plastic Rain



Fine plastic parts float in the sea off the Greek island of Crete.

KEY INSIGHT

Microplastics are everywhere. They float through our waterways, get carried into seawater, and evaporate into clouds, which then disperse and redistribute the plastics in rain—even in protected natural habitats like national parks and the French Pyrenees. Plastic rain is the new acid rain.

EXAMPLES

After a 14-month study that evaluated levels of microplastics in rainwater, new modeling indicates that more than 1,100 tons of microplastics are hovering above the Western United States. That's the equivalent of 120 million plastic water bottles falling from the sky, contaminating remote locations on the continent. Surprisingly this new modeling also indicates that 84% of airborne microplastics in Western North America come from roads outside major cities. The ocean is likely responsible for another 11% of the plastics lingering overhead. These microplastics, which are smaller than 5 millimeters, can come from plastic bags and bottles that break down after use or even from cleaning synthetic clothing in washing machines.

DISRUPTIVE IMPACT

A recent study published in *Nature* found that microplastics are reflecting sunlight back into space, resulting in a very slight cooling of the environment. However, this unintended case of geoengineering is ultimately bad for the climate and could result in making the climate hotter over time. Additionally, scientists don't yet know the long-term effects of inhaling or swallowing nanoplastics—additionally microbes and viruses are certainly capable of hitching a ride on tiny plastic particles. Research from the National Academy of Sciences attributes the recent increase in microplastics in our environment to pandemic-related changes in consumption and habits, as the demand for single-use plastics has increased since early 2020. This indicates that significant changes can result in a short period of time and from seemingly innocuous changes in habits.

EMERGING PLAYERS

- National Academy of Sciences
- Sea Turtles Forever's Blue Wave initiative
- VTT Technical Research Centre of Finland
- U.S. National Oceanic and Atmospheric Administration
- European Chemicals Agency
- Parverio

2ND YEAR ON THE LIST

Rewilding



The startup Colossal wants to bring thousands of woolly mammoths back to Siberia.

KEY INSIGHT

Rewilding is an integrative approach to environmental conservation and rehabilitation that focuses on the reintroduction of keystone species and the creation of safe corridors by which species can freely migrate. With climate change increasingly disrupting wildlife habitats and newly accessible technologies offering innovative rewilding techniques, the decades-old approach is taking on renewed significance.

EXAMPLES

The restoration of apex predators, keystone species (so-called ecosystem engineers), and beneficial plant life in native habitats can help revive natural communities, even after decades of drastic decline. This action is also known as translocation rewilding. Passive rewilding merely attempts to reduce human intervention in ecosystems, thus surrendering human-cultivated land back to nature. A third form of rewilding, Pleistocene rewilding, aims to reintroduce species or descendants of megafauna species from the Pleistocene era. Proponents of this practice arguing that the extinction event that happened almost 12,000 years ago left the ecosystem unbalanced. A team of scientists and entrepreneurs at the startup Colossal intends to do just that. In 2021 the company announced plans to genetically resurrect the woolly mammoth and reintroduce it to the Siberian tundra.

DISRUPTIVE IMPACT

Environmental conservation will require a suite of new technologies to actively reverse human-made damage and facilitate coexistence between nature and the industrialized world. If an integrative approach becomes the standard for corporate sustainability initiatives, rewilding will lead to market growth that benefits landscape architects, agriculture executives, automotive engineers, and real estate agents, among others. The acts of removing human intervention from certain ecosystems and repopulating endangered animals in specific locations can result in reduced carbon emissions. However, misuse or poorly applied instances of rewilding could carry risks, such as harming biodiversity and alienating communities. As organizations move to undertake drastic forms of Pleistocene rewilding, these risks will have to be weighed against the potential positive impact ushered in by de-extinction practices.

EMERGING PLAYERS

- WildEast
- Colossal
- Pleistocene Park
- Citizen Zoo
- The Rewild London Fund
- The Rewilding Institute
- Rewilding Europe
- Yale School of the Environment

3RD YEAR ON THE LIST

Seasteading



The city of Busan has approved an ambitious ocean settlement consisting of a series of interconnected platforms.

OCEANIX/BIG-Bjarke Ingels Group.

KEY INSIGHT

Seasteading is a colonization process wherein permanent human dwellings and settlements are constructed at sea. Although seasteading has previously been discussed as a way to establish utopian societies beyond government reach, the innovations that would make such colonies possible might also serve governments aiming to protect citizens from future flooding and rising sea levels.

EXAMPLES

In 2008, Google engineer Patri Friedman (grandson of Nobel Prize-winning economist Milton Friedman) founded the Seasteading Institute with funding from venture capitalist Peter Thiel. The goal: to set up a permanent community that could experiment with novel political and legal systems. In 2020, Grant Romundt, Rüdiger Koch, and Chad Elwartowski set out to build their utopian dream. They purchased a cruise ship, renamed it the MS Satoshi, and planned to build a society off the coast of Panama free from taxes, regulations, and fiat currency. Much to their disappointment, after four months, the three ceased operations of their seasteading experiments as strict regulations of the cruise ship industry made it untenable. UN-Habitat, the U.N. agency that covers urbanization, is working with Oceanix to build a floating city off the coast of Busan, South Korea. The project is projected to cost \$200 million and could be completed by 2025.

DISRUPTIVE IMPACT

Whether or not the utopian dream of new governments and innovative legal systems pans out, the architectural research being conducted now could prove fortuitous: With sea levels rising, future communities may need to be built at sea that incorporate renewable energy sources, indoor vertical farms, and underwater communications systems. Oceanix's Busan project with UN-Habitat reveals such tensions. These innovations will help build flood-proof habitats in ocean settings, but there are no plans for residents of Busan's floating habitat to benefit from any special rules or provisions. The visionary views of seasteading are now being appropriated by small governments for venerable but less than utopian applications.

EMERGING PLAYERS

- UN-Habitat
- Oceanix
- Seasteading Institute
- Ocean Builders

3RD YEAR ON THE LIST

Managing Digital Emissions



Our homes produce digital emissions with every post, command, and search we do.

KEY INSIGHT

Small, individual actions collectively contribute to a global impact on greenhouse gasses, but many consumers lack awareness of their contributions. Companies are leading initiatives to reduce energy costs, for example by relocating data centers to cold climates. Edge computing and 5G will reduce reliance on server farms for data processing, lowering the digital carbon footprint even further.

EXAMPLES

More than half of the global population uses the internet, and contributes to the rise of digital emissions. Because energy consumption accounts for a significant financial cost, universities and technology companies are making digital tasks more efficient. Stanford University is exploring how to make machine learning “green” with less energy-intensive algorithms and training sessions. Google is locating data centers in cold climate countries where nature provides free cooling for IT equipment, and the company is looking at more energy-efficient computer chips. Rather than relying on chips built for graphics processing, researchers discovered that neural network-specific designs can be five times more energy-efficient when training an algorithm.

DISRUPTIVE IMPACT

Reducing digital emissions will be important for businesses to hit company-wide emissions targets. Organizations are scrutinizing entire value chains for ways to limit the environmental impact of our digital lives. Internet service providers can now allow consumers to select routing based on the lowest carbon footprint, using the SCION internet architecture. These “green” networks should offer ISPs a competitive edge in cutting the carbon footprint of digital infrastructure. With the proliferation of 5G networks and edge computing, data processing will also become more localized rather than sent long distances for processing in the cloud—and that may also reduce energy usage. Regulation could force corporations to change how they use energy and require systems to track, monitor, and verify compliance.

EMERGING PLAYERS

- SCION
- Washington University in St. Louis
- The Korea Advanced Institute of Science and Technology
- DigiPlex
- Cloudflare
- Nokia
- Ericsson
- Firefox



The climate has changed. Has your skin care?

All-in-one protection from the full range of today's environmental harms.

SPF 150+ Won't clog pores Phthalate-free

Effective defense against*:

- | | |
|-----------------------|-----------------|
| Plastic Rain | Microbes |
| Acid Rain | Ozone |
| Necrotizing Pathogens | Nitrogen Oxides |
| Airborne Carcinogens | Carbon Monoxide |
| UVA/UVB/UVC Rays | Sulfur Dioxide |



Scan to receive a personalized formula for your own microclimate.

**These statements have not been evaluated by the Food and Drug Administration. This product is not intended to diagnose, treat, cure, or prevent any disease. Not intended for use in extreme climate crisis zones.*



8TH YEAR ON THE LIST

Anthropocene Age



Human action has left an indelible mark on Earth.

KEY INSIGHT

Whether a geological epoch or merely an event, our current time period—the “Anthropocene” (anthro for “man,” and cene for “new”)—is defined by the indelible mark that humans have left on Earth. The future will tell if our impact remains damaging, or if we set a more positive trajectory for our planet.

EXAMPLES

A new epoch follows a cataclysmic event. (For example, mass extinction of the dinosaurs followed an asteroid colliding with Earth.) Such events significantly and permanently alter the sedimentary and rock layers beneath the planet’s surface. In 2018, an international, independent team of scientists, called the Anthropocene Working Group, was moved through evidence to support the official declaration of a new geological epoch. Some critics question this move, pointing out that while other epochs have spanned millions of years, this selection of time dates back 400 years at most, and perhaps as few as 75 years. Given such timelines, if, as a species, we continue our reckless ways, the climate may be untenable for human life well before epoch status is achieved. The situation is dire—unless we discover how to channel this direct impact on climate to reverse trends.

DISRUPTIVE IMPACT

While scientists can get caught up in the debate over whether the Anthropocene is actually a geological epoch, or merely an event, the climate crisis and biodiversity collapse indicate that we are in the Age of Humans, a time when humanity is knowingly shaping the planet, rather than the planet shaping our species. The United Nations Development Programme has noted that the Anthropocene is the era “in which the dominant risk to our survival is ourselves.” Recognizing that humans have made a permanent, visible mark on Earth is the first step in studying the implications for our planet’s future. If we fail to recognize and take accountability for our culpability in these areas, the risk of demise could be realized more quickly than anticipated.

EMERGING PLAYERS

- Anthropocene Working Group
- International Union of Geological Sciences
- The Nature Conservancy
- Union of Concerned Scientists
- U.S. Geological Survey



No one disputes that people are a significant shaping force on our planet—but exactly how those impacts will be incorporated into the geologic record has been trickier to define, in part because the ‘how’ and ‘when’ of those impacts has varied across the globe.

— Jacquelyn Gill, associate professor of paleoecology and plant ecology at the University of Maine



9TH YEAR ON THE LIST

Green Tech



Mycelium could become an alternative material to plastic foams, such as polystyrene.

KEY INSIGHT

Fighting climate change will require a multipronged approach. As a species, we will have to adapt and create new habits, but along with that, green technologies will be incorporated in our strategies to reduce and even reverse our short- and long-term impacts on the environment.

EXAMPLES

More money than ever is being invested in climate and green technologies. Recently, two asset managers, TPG and Brookfield, closed \$12.4 billion in climate investment funds in one day, a substantial increase over funds committed to such technology in the past. The U.S. is undertaking a path to install offshore wind farms with the goal of producing 30 gigawatts of capacity by 2030. Yara International, a Norwegian company, has developed the world's first zero-emission, fully electric ship. South Korea just brought online one of the world's largest floating solar plants, which is capable of collecting 41 megawatts of power. The Korea Energy Economics Institute reports that floating solar power is set to quadruple by 2025. Australia just invested \$738 million to fast-track nascent low-emissions technologies, including carbon capture and storage.

DISRUPTIVE IMPACT

Climate change and new regulatory efforts could force the world to look for new, sustainable sources of energy, especially as species-wide changes to our actions and habits take shape slowly or not at all. As green tech begins to mature, new technologies and scientific breakthroughs continue to generate significant interest. Investments are growing as more governments pledge funding for green-tech solutions that double as economic recovery efforts.

EMERGING PLAYERS

- LanzaTech
- Air Company
- Twelve
- Carbios
- CO2 Solutions
- The Ocean Cleanup
- Biome Markers
- Algenesis
- Eforce
- Fuergy

Green Tech Trends



The Ocean Cleanup was able to collect 20,000 pounds of trash from the Pacific Trash Vortex.

■ Ocean Iron Fertilization

Wind transports dust from the Sahara to the Atlantic, and iron contained in the dust fertilizes the growth of phytoplankton in the ocean. Over time, phytoplankton use sunlight, nutrients, carbon dioxide, and water to produce oxygen and nutrients for other organisms—in fact, these microscopic organisms feed the oceans' fish and animals and are responsible for producing around 50% of the air we breathe. In 2022, experiments will test whether it's possible to supercharge and speed up the process by intentionally dropping large iron deposits in oceans. If it works, scientists believe that iron-rich phytoplankton could absorb between 10 billion to 30 billion tons of greenhouse gasses each year.

■ CO₂-Based Materials

Carbon dioxide captured from smokestacks or even just from the air sur-

rounding us can be repurposed to make a vast array of materials. The production of cement, a core component of concrete, is responsible for 7% of total global carbon dioxide emissions. Engineers are working to fundamentally change concrete technology, to create CO₂-infused concrete that not only locks up greenhouse gasses but is stronger and more bendable than traditional concrete. Recycled carbon emissions have also been used by LanzaTech and Lululemon to create fabrics for activewear. CO₂ is also used to manufacture diamonds, and Air Company even uses it in the production of impurity-free vodka. The company Twelve has used CO₂ in the production of jet fuel, parts for car interiors, ingredients for laundry detergents, and lenses for sunglasses. CO₂ has been used in innovative ways to manufacture new materials, but whether consumers will accept them remains to be seen.

■ Bacterial Storage for CO₂

Scientists are building tubular bioreactors, filling them with green algae, and letting them eat away at the carbon captured from the environment. Quebec City-based CO₂ Solutions genetically engineered a strain of E. coli bacteria to produce special enzymes capable of eating carbon dioxide and converting it into a harmless bicarbonate.

■ Plastic-Eating Enzymes and Bacteria

Humans' habitual use of single-use plastics became even more pronounced during the COVID-19 pandemic, as people used more consumables and disposable masks. Waste reduction will depend on habit change, but additional solutions might come in the form of bacteria and enzymes. Dating back to 2016, scientists in Japan discovered bacteria that could decompose plastic. One day, researchers hope, industri-

Green Tech Trends

al-scale facilities could use enzymes to decompose or eat large piles of plastics in landfills, or to spray such enzymes on the massive amounts of plastics that accumulate in oceans and rivers. Until then, French biotech company Carbios is leading the way by developing a demonstration plant that will biodegrade PET plastic using enzymes and bacteria. While bacteria cannot break down plastics all the way back into core elements, Carbios intends to convert PET plastic into a feedstock for creating more plastics.

■ Filtering the Ocean of Plastic

The notorious pile of trash floating in the Pacific Ocean is bigger than first estimated. It is actually two distinct collections of garbage, collectively also known as the Pacific Trash Vortex. In 2018, researchers found that it is 16 times larger than original estimates, at least three times the size of France, or a total of

617,763 square miles. It is estimated that the Pacific Trash Vortex alone accounts for 1.8 trillion pieces of plastic. Collectively, 5.25 trillion pieces of plastic are in the oceans, with 46,000 pieces in every square mile. By 2040, the amount of plastic in our oceans could triple. Fortunately, a number of nonprofits and startups have ambitious goals to clean the oceans. In October 2021, nonprofit The Ocean Cleanup demonstrated that its installation named Jenny, which is basically an artificial floating coastline towed between two vessels, could catch plastic and then funnel it into a net. During its trial, Jenny was able to collect 20,000 pounds of trash out of the Pacific Ocean, a small step toward The Ocean Cleanup's goal of removing 90% of floating ocean plastic by 2040. While this is evidence that a solution could exist for clearing the Pacific Trash Vortex, scientists have discovered dozens of coastal species now call the trash collec-

tion home. As we develop processes to amend problems we have created, new challenges arise.

■ Sandcastling Glaciers

Sand is stronger than we once thought. A conservation project from Princeton University seeks to build massive piles of sand or other materials on the seafloor to serve as walls around glaciers—like scaffolding to prevent them from collapsing. Warm seawater far beneath the surface of the ocean can destabilize the foundations of glaciers, causing pieces to break off and melt. Shoring up their foundations could keep glaciers submerged in the icy upper layers of water, and—theoretically—prevent them from melting. It's not a perfect method for all glaciers, but it can help.

■ Reflecting Sunlight

Scientists are working on building enormous, mirrored parasols in the

stratosphere, with the idea that they would reflect sunlight back into space and theoretically cool the Earth's atmosphere over time. Alternatively, the Keutsch Research Group at Harvard University had grand plans to launch the first-ever aerosol injection experiment known as the Stratospheric Controlled Perturbation Experiment. The scientists had received financial backing from Bill Gates to inject nontoxic calcium carbonate dust into the atmosphere. A trial of the project was set to occur in the summer of 2021 in Sweden, but a group of Swedish environmental organizations and the Indigenous Saami Council demanded that it be canceled. Due to the backlash, the project was pushed back to 2022 at the earliest.

■ Solar Radiation Management

This controversial technique, which has not yet been tried at scale, involves injecting tiny sulfur dioxide particles

into the sky that would reflect sunlight back into space. The idea comes from volcanoes; scientists point to an eruption 200 years ago that caused an unusual cold snap, triggering unseasonal summertime frosts. The Climate Intervention Biology Working Group, a collaboration between Michigan State University and Stony Brook University, intends to pursue the volcano-inspired idea. These researchers hope to create an artificial cloud of aerosols in the stratosphere. Ideally, this cloud could be replenished and moved to specific locations to help achieve certain temperatures there. The group points out that the technology needed to put aerosols in the atmosphere to reflect sunlight are cheaper and more easily attainable than alternative practices such as sequestering carbon from the atmosphere. One challenge is that an uneven distribution of aerosols could affect local ecosystems and result in increased acid rain.

Green Tech Trends



Cloud seeding is being used to mitigate drought and to temporarily reduce smog.

■ Cloud Injections

This geoengineering technique, also known as marine cloud brightening, targets low-level clouds over the ocean and makes them more reflective by spraying seawater into the air, thereby injecting particles of salt into the clouds. In theory, as water vapor collects on the surface of the salt particles, the result is additional cloud droplets that reflect more sunlight back into space. However, research from NOAA's Chemical Sciences Laboratory and CIRES discovered that this technique will require much specificity and cannot merely rely on spraying salt water into the air. If particles are too large, these large droplets will collide with each other and descend to the earth as rain. Particles that are too small will result in increased evaporation and less cloud cover.

■ Bioengineered Trees

CO₂ is the undisputed culprit when it comes to climate change. But what if we could just suck it out of the air? Trees do that naturally, but after years of deforestation, we simply do not have enough of them to make a sizable impact. Scientists at Columbia University are developing plastic trees that passively soak up carbon dioxide from the air and store it on a honeycomb-shaped "leaf" made of sodium carbonate, similar to baking soda. So far these fake trees prove to be a thousand times more efficient at soaking up CO₂ than real trees. The next challenge will be to purify the carbon dioxide or bury it safely beneath the ground or the ocean floor. One approach is to convert atmospheric CO₂ into carbon nanofibers that can be used for consumer and industrial products, including wind turbine blades or airplanes. Another option comes

from chemists at George Washington University who are experimenting with what they dub "diamonds from the sky." The scientists bathe carbon dioxide in molten carbonates at 750 degrees Celsius, then introduce atmospheric air and an electrical current on nickel and steel electrodes. The carbon dioxide dissolves, and carbon nanofibers form on the steel electrode.

■ Mycelium Revolution

Mycelium is the vegetative part of a fungus, composed of thread-like filaments of tissue known as hyphae. It is basically the life-support system of fungus. Because mycelium is easy to grow and fully biodegradable, researchers have been exploring alternative uses for it. The company Ecovative is using mycelium to close the loop of material production, using mycelium in products to replace plastic foam, plastics, and leather. My-

Green Tech Trends



Xiulin Ruan, a Purdue University professor of mechanical engineering, holds up his lab's sample of the whitest paint on record.

Image credit: Purdue University.

celium also has potential for use in meat substitutes. Because mycelium is nature compatible, products using the material can passively be returned to the earth at the end of their life cycles. As the global packing industry grows to an estimated \$50 billion later in the decade, mycelium could provide an alternative to petroleum-based materials.

■ Ultra-White Paint

As the threat of global warming persists, engineers at Purdue University have manufactured the whitest paint to date. The engineers hope that coating buildings with this paint could one day eliminate the need for air conditioning. They estimate that covering a roof area of 1,000 square feet could produce a cooling power of 10 kilowatts. This iteration of white paint reflects up to 98.1% of sunlight by containing a high concentration of barium sulfate. This chemical compound that results in the very reflec-

tive nature of the paint also comprises different-sized particles. The varying sizes of the particles create more reflectivity by scattering more light spectrum from the sun. Purdue engineers testing the paint discovered that it is capable of keeping surfaces 19 degrees Fahrenheit cooler at night and 8 degrees Fahrenheit cooler during the day.

■ Artificial Rainstorms

Parts of the Middle East and Africa could be uninhabitable by 2050 due to extreme heat. In an effort to help regulate heat in the Middle East, the United Arab Emirates has begun trying to harness the power of rain. A video released by a UAE weather agency showed heavy rain falling in the region, something that is rare in the desert. Even as clouds form in desert climates, drops of rain that do get heavy enough to fall from these clouds often evaporate before hitting the ground. However, electrical

charging of clouds can cause small droplets to collide and form bigger droplets, to the point that they become big enough to reach the ground before evaporating. To create this electrical charge, the UAE used drones that dispel electrical charges.

Growing Exotic Animals • Mid-future pessimistic scenario

Hunting endangered species has always been a thrill of the top 1%. Thanks to genetic cloning, animals are created for the sole purpose of killing them for millions of dollars in private safari hunting parks. The cloning takes mere months, and zoos made generous donations of iced cell banks of species such as leopards, rhinoceroses, and gorillas. Meanwhile, efforts to protect these species in the wild have diminished due to environmental changes and lack of funds, forcing the privileged few to keep their practice out of the public eye.



From: **The Hunt™**
To: wilson@trillionaires.com

Dear Mr. Wilson,

Thank you for your interest in The Hunt™ and our spectacular experiences of hunting the rarest of species—animals that may be near extinction or extinct in the rest of the world. It's truly an unmatched experience you'll only find at our park.

You asked about the species currently available, and I'm happy to report that our animals are exclusively made to order. The cloning process takes about five months, and we usually wait until the animal has reached maturity before releasing it into the safari.

While this requires some planning on your side (hunting experiences are typically booked two to five years in advance, depending on the animal), we have found that mature animals increase the challenge of the hunt, making for a much more enjoyable experience. Hunting immature animals is generally discouraged, although exceptions are sometimes made for inexperienced hunters (such as father-and-son hunting outings).

Please let me know if you have any further questions. I am happy to assist in any way I can.

Sincerely,

Jeb | The Hunt™ | *It's just you against nature.*

4TH YEAR ON THE LIST

Environmental, Social and Corporate Governance (ESG) Programs



Teva became the first pharmaceutical company to issue sustainability-linked bonds.

Photo Credit: Teva

KEY INSIGHT

For various reasons, companies of all sizes are leading with sustainability as part of their core values. Whether driven by public opinion to adopt better practices or because better sustainability behaviors can indicate to investors that a company can better anticipate future risk, companies are reporting their environmental, social, and corporate governance (ESG) efforts now more than ever.

EXAMPLES

Salesforce has been a proponent of responsible capitalism. At its yearly conference, Dreamforce, the software company announced in 2021 that it had reached effective net-zero energy usage in its entire value chain. To achieve this, Salesforce has implemented 100% renewable energy whenever possible and purchased carbon offsets when not. The company also offers its proprietary Sustainability Cloud as a software product to other organizations, enabling them to better manage their own climate efforts. Drug manufacturer Teva Pharmaceuticals made an uncommon move to sell \$5 billion in bonds with links to sustainability measures. Teva will release performance reports on climate action as well as on the availability of medications to lower-income countries. If the company fails to meet its established goals, investors will receive higher payments. This could create a new precedent for companies holding themselves accountable to their ESG goals.

DISRUPTIVE IMPACT

There are now 534 index funds centered on sustainability, overseeing a combined \$250 billion in assets. The industry could grow to an estimated \$53 trillion by the end of 2022. Over the past several years, investors have asked companies to provide reporting to back up their environmental, social, and governance promises, and many have responded with annual ESG reports. Independent agencies such as MSCI, Sustainalytics, and S&P Global conduct ESG ratings of other organizations, but there is little consistency between the groups. Topl, a blockchain ecosystem, wants to help companies verify their ESG claims with full transparency and traceability. Such technology could one day be used to standardize the practice among independent rating institutions, placing more responsibility on corporations to clean up their acts.

EMERGING PLAYERS

- Salesforce
- Facedrive
- Topl
- Teva Pharmaceuticals
- Autodesk

Environmental, Social and Corporate Governance (ESG) Programs



COP26 brought together 120 world leaders and more than 40,000 registered participants to discuss climate change, sustainability plans and policy solutions to secure a net zero world.

Credit: UNFCCC

■ Strategic Sustainability Plans

Unilever's Sustainable Living Plan sets sustainability targets for sourcing, supply chain, and production throughout its operations. A decade ago, Unilever announced it would double its business while cutting its environmental impact in half. Allergan, the maker of Botox, developed ways to conserve water and energy in its operations and supply chain. Patagonia sets the pace for every industry: It encourages repairing rather than replacing its products, it uses natural rubbers and upcycled plastic bottles, and it strives to minimize packaging waste. Two years ago, Patagonia took its sustainability efforts a step further, saying it would produce custom-logo vests and jackets only for companies that can prove they align with Patagonia's corporate values.

■ Supply Chain Sustainability

Supply chains are inherently challenging when it comes to ensuring sustainability. Disparate elements that hinder sustainability include energy use, labor conditions, cold-chain carbon emissions, and contamination of local environments. However, more companies have started reporting their ESG policies for suppliers. Such a move could become mandatory for some global multinationals. In 2021, Germany passed new laws that force bigger companies to establish due-diligence procedures that prevent human-rights and environmental abuses within their global supply chains. Companies will also be required to report any misdeeds by foreign suppliers. This could set a precedent for more governing bodies to establish similar regulations as a means of monitoring global supply chains. To improve industry sustainability, H&M has piloted

Treadler, a service that outsources the supply chain to smaller companies in an effort to help them overcome barriers and accelerate sustainable change.

■ Shipping Industry ESGs

It's no mystery that the shipping industry is a huge contributor to climate change due to its carbon dioxide emissions and unquenchable thirst for fuel. Shipping accounts for 90% of world trade and contributes 3% of the world's CO2 emissions. An estimated \$2.4 trillion will be needed for the industry to reach net-zero emissions by 2050. Shipping companies are feeling increasing pressures as ESG-driven requests are prompting more actions from banks that finance these operations. Shell Oil attempts to improve fuel efficiency with air bubbles. The oil company installed a new system on the hull of a ship developed by London-based Silverstream

Technologies. Steel boxes welded to the ship's hull and air compressors create a layer of microbubbles between the vessel and the water. The improved hydrodynamics of this design helped the ship move faster and more easily through the water, and resulted in 5% to 12% fuel savings. Meanwhile, the market for hybrid and electric boats is growing. The world's first autonomous electric container ship, Yara Birkeland, completed its first trip in Norway, traveling 8.7 miles. While short in nature, this first voyage has deeper implications for an industry feeling the added pressures to go green.



00

01

02

03

04

05

06

07

08

09

10

11

12

13

Climate, Energy & Space

Energy

1ST YEAR ON THE LIST

Electric Wind



An MIT plane is propelled by electric wind.

Image credit: Christine Y. He/MIT News Office.

KEY INSIGHT

Also known as ionic wind, electric wind is created when charged particles move between electrodes in the air. As molecules collide, they transfer momentum and generate a breeze.

EXAMPLES

The propellers and turbines that lift airplanes into the sky are powered by fossil-fuel combustion. What if electric wind could allow planes to fly without needing moving parts at all? In 2018, a prototype called the EAD Airframe V2 was the first plane to fly using electric wind as thrust. The Adriatic Sea is home to some of the most intense winds in the world—bridges in Slovenia and Croatia are closed often due to unsafe conditions. Researchers are developing electric wind generators, which could be fixed to bridges and automatically calm wild winds to ensure safe passage for truck and car drivers.

DISRUPTIVE IMPACT

Harnessing the wind is a promising concept—but will it scale up? Induced breezes could eventually power certain types of aircraft. Tweaks to current automobile designs could leverage wind technology for greater efficiencies and a reduced reliance on both fossil fuels and electricity.

EMERGING PLAYERS

- Jožef Stefan Institute
- KTH Royal Institute of Technology
- MIT Lincoln Laboratory Autonomous Systems Line
- King Abdullah University of Science and Technology

3RD YEAR ON THE LIST

Building Better Batteries



Tesla's attempt at a million-mile battery could give new life and applications for batteries after their initial use in an electric vehicle.

KEY INSIGHT

The race to produce a lighter, more efficient battery is more competitive than ever. New technology promises to extend the life of car batteries, which could reduce the degradation process and allow batteries to outlive the vehicles they power, providing new applications at a vehicle's end of life.

EXAMPLES

With Tesla's development of the "million mile" project, the company has extended its partnership with Jeff Dahn, perhaps the world's preeminent lithium-ion battery researcher, by five years. Exploring lower cost and extended life span, this research also focuses on increasing energy density, safety, and the use of sustainable materials. After initial use in sports cars, million-mile batteries could be repurposed for fleets of electric cabs, and later for grid energy storage and backup power systems. Alternatively, Ford and BMW are heavily investing (\$130 million) in a startup called Solid Power, which is researching solid-state batteries. While not yet used in mass-market cars, this technology promises greater energy density, increased safety, and longer range for electric vehicles. Another safer alternative, graphene aluminum-ion battery cells from Graphene Manufacturing Group, can charge 60 times faster and hold three times more energy than other batteries.

DISRUPTIVE IMPACT

As climate change intensifies, batteries will become increasingly essential, not just for vehicles but for power storage systems and grid technology. Better, longer-lasting batteries improve energy usage and efficiency, while allowing us to communicate, connect, and continue daily activities during energy disruptions. Realizing the importance of battery technology, the U.S. Department of Energy has funded \$209 million for 26 new laboratory projects focused on electric vehicles, advanced batteries, and connected vehicles. As EVs become more standardized, the technology will serve dual purposes, as vehicle-to-grid technology catches on. EVs will help stabilize the grid during peak energy times and serve as backup power supplies during power outages. By 2027, the global battery market could reach \$310.8 billion. As batteries begin to hold longer charges and can be recharged in substantially shorter periods of time, more applications will become known.

EMERGING PLAYERS

- Northvolt
- Redwood Materials
- Solid Power
- Ford
- BMW
- QuantumScape
- Contemporary Amperex Technology
- Tesla
- General Motors
- Panasonic

2ND YEAR ON THE LIST

Fusion Power



A rendering of Commonwealth Fusion Systems' compact nuclear fusion reactor known as SPARC.

Photo courtesy of Steve Jurvetson/ Flickr.

KEY INSIGHT

While the promise of break-even fusion power still might be more than a decade away, milestones are making it more palpable. Appropriating the process that serves as the power source of stars is one of the more encouraging options for producing cleaner energy.

EXAMPLES

Until recently, only state-run fusion projects could establish the necessary resources to undertake large-scale fusion projects. The world's largest fusion effort, ITER, is propped up by 35 nations, receiving at least \$22 billion in support to build its tokamak system, a machine that uses magnetic fields to confine plasma to create fusion power. Cambridge, Massachusetts-based Commonwealth Fusion Systems, on the other hand, strives to have the first net-energy fusion device by 2025 by employing high-temperature superconductors that will enable smaller and more cost-effective tokamak technology. Its fusion system, SPARC, is projected to be one-fortieth the size of ITER. The company will benefit from investments totaling \$1.8 billion from investors including Bill Gates, George Soros, and John Doerr. A competitor backed by Jeff Bezos, General Fusion, recently raised \$130 million to build a fusion demonstration plant in the U.K.

DISRUPTIVE IMPACT

While the fusion-technology sector has traditionally been limited to programs overseen by governments, it is now increasingly being driven by private enterprise (albeit often state-assisted enterprise). There are now more than 30 private fusion companies throughout the world. Of those, 18 have revealed their funding, which cumulatively exceeds \$2.4 billion. Because of this increase in private investment, innovation in this domain can evolve beyond some of the more typical designs previously issued by national and international agencies. With this shift, advancements in the materials, computing, and other technologies needed to bring fusion power to reality become much more plausible. Fusion plants could potentially arrive sooner and for much cheaper.

EMERGING PLAYERS

- Commonwealth Fusion Systems
- General Fusion
- Helion
- TAE Technologies
- Zap Energy
- National Ignition Facility
- Korea Institute of Fusion Energy
- Korea Superconducting Tokamak Advanced Research
- First Light Fusion

2ND YEAR ON THE LIST

Clean Hydrogen



Clean hydrogen, generated from using excess renewable energy sources, could one day provide low-carbon fuels for planes and ships.

KEY INSIGHT

Hydrogen is a useful energy source due to its abundance, ubiquity, versatility, and high energy content. As the price comes down to produce it cleanly, it could play an important role in transitioning much of the world away from carbon-based energy sources.

EXAMPLES

There are many ways to produce hydrogen, and each process has an associated color. The most common form of hydrogen production, known as “gray” hydrogen, requires natural gas, or methane, which results in high carbon emissions. “Green” hydrogen, or “clean” hydrogen, uses surplus renewable energy sources, such as solar or wind power, to separate the two hydrogen atoms from the oxygen atom. This process accounts for only 0.1% of hydrogen production, but efforts are underway to change that. Researchers from The University of Texas at Austin have developed a low-cost method of using sunlight to extract oxygen molecules from water, resulting in hydrogen. Researchers from the Massachusetts Institute of Technology have taken a different approach, by using scrap aluminum and forcing a reaction with water to produce emission-free hydrogen. Whatever process is ultimately used at scale, clean hydrogen could be used for fuel-cell vehicles, heat-producing boilers, and electricity-generating gas turbines.

DISRUPTIVE IMPACT

Hydrogen is an abundant resource that doesn’t generate carbon emissions from its use. However, many of the processes to isolate hydrogen as a usable source are responsible for creating carbon emissions. The United States produces and consumes roughly 10 million metric tons of hydrogen each year. In 2020, globally, we consumed 90 million tons of hydrogen. Unfortunately, virtually all of this is gray hydrogen. Currently, the cost to produce clean hydrogen is three times that of gray hydrogen, while the cost to produce gray hydrogen is \$2.28 per kilogram. Initiatives such as a green hydrogen hub in the United Arab Emirates backed by \$5 billion in investment, and an investment of over \$2 billion in electrolysis projects by London-based Ineos, could bring the cost of producing green hydrogen below the cost of producing gray hydrogen by 2030.

EMERGING PLAYERS

- Kubagen
- Clean Hydrogen Future Coalition
- TotalEnergies SE
- Air Liquide SA
- Vinci SA
- ITM Power
- Ineos



**“We do not inherit the earth from
our ancestors, we borrow it from
our children.”**

— Indigenous Proverb



3RD YEAR ON THE LIST

Grid Management



National power grids need an overhaul.

KEY INSIGHT

In many countries, government agencies and private companies distribute energy to citizens via an electric grid that's made up of a sprawling network of generators and connectors. Increased demands for power, failures to maintain these grids, erratic climate patterns, and even cybersecurity attacks will pose new challenges over the coming decades.

EXAMPLES

In the United States, aging electrical systems are being pushed beyond their limits. According to the U.S. Energy Information Administration, the average American home experienced more than eight hours without power in 2020. This total doubled in five years. Electricity outages affected millions of people in 2021 due to winter storms in Texas, heat waves in the Pacific Northwest, and Hurricane Ida. For the latter, power outages contributed to 14 deaths in Louisiana. China continues to experience hiccups with its energy grid. In early 2021, increased global economic activity created excessive demand for electricity in the coastal regions of China where many large factories operate. During the summer, industrial power rationing began in many Guangdong cities. Then, in September, utility providers in more than 20 Chinese provinces had to restrict power demand because of unseasonably warm weather in the South and cold weather in the North.

DISRUPTIVE IMPACT

Grid failures cost millions and put lives in danger. While health and safety are the primary concerns, power cuts also create shortages of global goods. There are additional concerns that utility company equipment isn't being repaired or modernized fast enough and that maintenance will become more difficult amid climate change and new power demands. The U.S. has begun to address the issue. The infrastructure bill signed by President Joe Biden allocates \$100 billion for power grids and a new Grid Deployment Authority. A new power grid will need to be resilient enough to withstand extreme weather events, integrate with new sources of renewable energy, support distributed sources of energy, and meet changing consumer needs. While upgrades are necessary, Biden's pace of deployment might be too modest to meet the demand of new low-carbon goals. Better solutions will have to be devised to keep up with fast-changing environmental conditions worldwide.

EMERGING PLAYERS

- Schneider Electric
- Scale Microgrid Solutions
- Itron
- NV5 Global
- Quanta Services
- AutoGrid
- Bloom Energy
- Origami Energy

5TH YEAR ON THE LIST

Charging Stations



An Electrify America charging station at the Brea Mall in Orange County, California.

KEY INSIGHT

By the decade's end, increased production of electric vehicles in combination with private and public funding for nationwide charging networks will make the switch to electric vehicles viable for more consumers. The adoption of direct-current fast charging and new technology to increase charging speeds will be the true difference maker.

EXAMPLES

As of November 2021, according to the U.S. Department of Energy, the U.S. has more than 48,000 public EV charging stations and roughly 122,000 charging ports, primarily consisting of Level 2 charging (requiring 3–8 hours to fully charge) but also including some direct-current fast charging connectors (able to charge 80% in 20–30 minutes). In the infrastructure bill signed by President Biden, \$7.5 billion will go toward increasing the number of charging stations to 500,000 by 2030 (primarily the slower, Level 2 charging). Electrify America will focus on faster charging options, building out 1,800 fast-charging stations by 2025. The expansion will grow Electrify America's network to 49 states and add an electric vehicle charging highway in the upper Midwest. 7-Eleven plans to install 500 direct-current fast charging ports across North America by the end of 2022.

DISRUPTIVE IMPACT

As direct-current fast charging grows a broader footprint nationwide, the adoption of electric vehicles will increase as consumers gain a greater ability to quickly charge their vehicles. Ford, in partnership with Purdue University, has developed a prototype for a liquid cooling system integrated with charging cables that could result in a full recharge of an electric vehicle in under five minutes. Other convenience stores might follow 7-Eleven's lead and add fast charging stations. They stand to benefit from owning and operating charging ports themselves. The three biggest U.S. automakers—Ford, General Motors, and Stellantis—have jointly pledged that 40% to 50% of vehicles they produce will be zero-emission by decade's end. As a result, greater numbers of the population will be incentivized by availability to make the switch to electric.

EMERGING PLAYERS

- Electrify America
- 7-Eleven
- GM
- EVgo
- Tritium
- Blink Charging

4TH YEAR ON THE LIST

Renewable Energy



Wind turbines and solar panels accounted for about 290 gigawatts of new renewable power in 2021, a 3% increase in growth from the previous year.

KEY INSIGHT

In many markets around the world, renewable energy is already cheaper than nonrenewable energy. Renewable sources include wind, tides, geothermal heat, and sunlight, but new possibilities are being explored. Renewable energy is integral for meeting necessary net-zero emission goals.

EXAMPLES

According to the International Energy Agency, wind turbines and solar panels accounted for about 290 gigawatts of new renewable power in 2021, a 3% increase from the previous year. Solar, hydrogen, and wind power have accounted for all growth in power generation since 2020 as generation from coal, natural gas, and nuclear plants have declined. By 2026, carbon-free power sources are projected to add up to 4,800 gigawatts globally, an increase of 60% over 2020 levels. China is the global leader when it comes to capacity additions. Last year, China began building the first 100 gigawatt phase of a solar and wind buildout that should result in hundreds of gigawatts deployed in the country's desert regions. This plan will represent a considerable amount of China's aggressive goal to reach 1,200 gigawatts of solar and wind capacity by 2030 (a goal the country is projected to reach by 2026).

DISRUPTIVE IMPACT

Despite the recent achievements in renewable capacity, globally we are still behind on establishing a net-zero energy sector. For that to become viable by 2050, average annual additions of renewables must double over what the International Energy Agency expects from the next five years. President Biden's Build Back Better plan allocated \$555 billion toward climate and clean energy. Under this proposal, individuals would receive tax credits for weatherizing their homes and installing solar panels, and businesses would receive credit for producing more clean energy and new clean energy products. Researchers from the University of Massachusetts Amherst have developed an air-powered generator that uses protein nanowires to produce electricity from moisture in the air. When such alternatives scale, coupled with the current trajectory of renewables, traditional petroleum companies will feel the looming threat of replacement.

EMERGING PLAYERS

- Prometheus Fuels
- SunPower Corp.
- Renewable Energy Group
- Sunnova Energy
- Nexamp
- Energy Vault
- First Solar
- NextEra Energy
- ReNew Power

5TH YEAR ON THE LIST

Ultra-High-Voltage Direct Current and Macro Grids



KEY INSIGHT

In the near future, we will transport clean energy from production sites to demand areas using a new kind of power grid now being tested in China. If geopolitical tensions remain at bay, transferable energy will make collective energy grids more resilient.

UHVDC could lead to a transcontinental energy "internet."

EXAMPLES

China invested \$88 billion to build macro grids and a new kind of transmission system—ultra-high-voltage direct current (UHVDC). The country's plan is to essentially provide "the global energy internet." China first pitched this idea to the United Nations over six years ago, and countries might now overcome their initial hesitance to adopt because of increased emphasis on renewables. Changing priorities could present a case for China's UHVDC. China has moved forward with the project even as it has awaited wider buy-in. Last year, the country built a 970-mile-long, 800-kilovolt UHVDC line costing \$3.45 billion. This line transported solar- and wind-generated power from the Tibetan plains to the center of China. The country also constructed a 1.1-million-volt cable that is capable of transmitting 12,000 megawatts of power 2,000 miles from the mountain and desert regions of Xinjiang Province to Shanghai.

DISRUPTIVE IMPACT

A national direct current macro grid could drastically lower emissions in an affordable way without compromising access to electricity. It could also redistribute power to areas experiencing energy shortages and blackouts. The ability to generate and transport energy in times of crisis could become a critical political and economic advantage, and impact where businesses operate. Such a system could help prevent incidents such as power blackouts experienced in Texas in early 2021.

EMERGING PLAYERS

- State Grid Corp. of China
- China Southern Power Grid Co.
- Macro Grid Initiative
- ABB
- TransWest Express Transmission Project

3RD YEAR ON THE LIST

Zero-Carbon Natural Gas



Carbon capture technology uses filters to remove carbon dioxide from the atmosphere.

KEY INSIGHT

Natural gas can be part of our low-carbon future and might be integral for meeting net-zero carbon futures. When all carbon dioxide byproduct from natural gas production is successfully captured, the result is zero-carbon natural gas.

EXAMPLES

Natural gas plants of the near future may capture all of their emissions at zero cost using a technology called carbon capture and storage, or CSS. This process will result in power generation at the same cost or less as standard natural gas, even as it captures all carbon dioxide that is released. While the tech has been around for decades, it has not been deployed at scale. In November 2021, a natural gas plant in La Porte, Texas, allegedly became the first in the world to deliver emissions-free electricity to the grid. To accomplish this feat, the plant has employed Net Power's technology to capture most of the released CO₂, while the remainder is stored underground or used in industrial processes.

DISRUPTIVE IMPACT

A significant amount of carbon emissions come from natural gas production that still accounts for 32% of U.S. electricity and 20% of worldwide consumption. The U.S. Department of Energy recently announced that it would use \$45 million in funding for 12 different carbon capture and storage projects, capable of capturing a minimum of 95% of CO₂ emissions from natural gas power and industrial facilities. As more governments and businesses pledge zero-carbon futures, more natural gas companies will recognize they need contingency plans to generate cleaner natural gas. CSS technology could result in carbon-free energy produced from fossil fuels much more cheaply than by nuclear power plants. This could serve as a transitional power source as longer-term power solutions are potentially decades away.

EMERGING PLAYERS

- Net Power
- Exelon Generation
- McDermott International
- 8 Rivers Capital
- EnCap Flatrock Midstream
- Elysian Carbon Management
- Oxy Low Carbon Ventures
- Toshiba

3RD YEAR ON THE LIST

Floating Nuclear Reactors



SEABORG

Seaborg Technologies deploys compact molten salt reactors on floating barges worldwide.

KEY INSIGHT

Modular floating nuclear molten salt reactors provide a safer alternative to traditional nuclear reactors. Rapid mass-manufacturing of these units will give multiple regions quicker access to safer nuclear power.

EXAMPLES

While Russia launched a floating nuclear power plant with two nuclear reactors called the Akademik Lomonosov in 2020, startup Seaborg Technologies of Copenhagen, Denmark, is using compact molten salt reactors the size of shipping containers to deploy on floating barges worldwide. These molten salt reactors are better equipped to avoid disasters. A liquid salt mixed in with the fuel acts as a coolant, preventing the fuel from melting down or exploding. Besides being much safer, molten salt reactors are less complex and lower in cost. The power barges that Seaborg plans to deploy are projected to have an operational lifetime of 24 years and are capable of producing 200 to 800 megawatts of electricity.

DISRUPTIVE IMPACT

While nuclear power generation has traditionally been risky, molten salt reactors present a safer, cheaper, and more compact option for nuclear power. Following the approach of Akademik Lomonosov, Seaborg Technologies will benefit from modular design, preventing the need to buy up land to develop nuclear power plants. This business model makes it possible to produce reactors in bulk at a single facility and deliver them by barge on a much shorter timeline than the energy industry's traditional plant manufacturing methods. Higher safety and smaller sizes will give Seaborg Technologies a competitive advantage for expanding its scope of impact with available nuclear power.

EMERGING PLAYERS

- Seaborg Technologies
- Akademik Lomonosov
- RusHydro
- Rosatom

1ST YEAR ON THE LIST

Wireless Power Transfer



Stanford engineers have developed a wireless charging system that can transfer electricity to receivers with variable distances.

KEY INSIGHT

The ability to transfer significant amounts of energy wirelessly may seem far-fetched. However, advances in this area indicate that this process is increasingly viable. As scalable solutions are developed, devices will become lighter weight (with smaller batteries) and more efficient.

EXAMPLES

The desire for wireless power transfer dates back more than a hundred years to the idiosyncratic inventor and engineer Nikola Tesla. Today, engineers from Stanford University have developed a wireless charging system that can transfer electricity to receivers with non-fixed distances. Researchers were able to achieve a 92% efficiency with the ability to transmit 10 watts of electricity up to 3 feet away. Meanwhile, the Indiana Department of Transportation announced a wireless charging highway for electric vehicles. The pilot program will result in a quarter-mile-long stretch of wireless charging pavement. WiBotic, responsible for wireless charging systems for autonomous drones and robots, has received safety approvals in Europe for its TR-301 high-power transmitter. Startup Electric Sky is using funding from DARPA to develop a demonstration test for its new wireless long-distance transmission technology.

DISRUPTIVE IMPACT

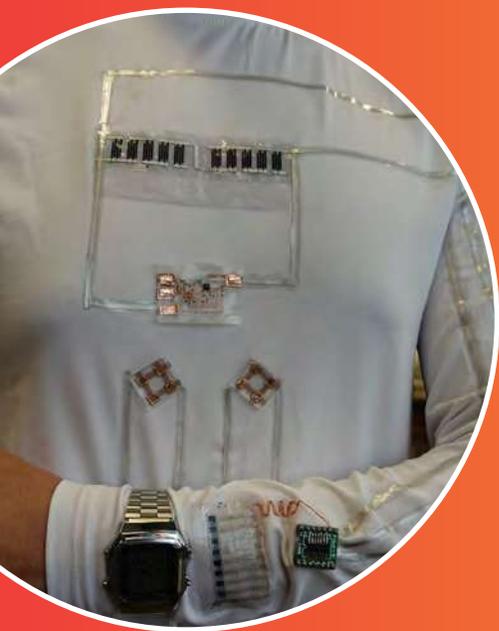
Most of our experiences with wireless power transfer are limited to mobile phones or electric toothbrushes that still require contact with a charging source. However, developments in this area have astounding potential. Once the technology is scaled, it can be used to charge robots in factories, drones in midflight, and even electric vehicles in motion. When it comes to EV applications, benefits include extending vehicle range, which in turn will encourage more widespread adoption of EVs. Additional benefits include prolonging battery life, as batteries could routinely “graze” energy, rather than fully depleting their supply and recharging from empty, which causes degradation over time. More important, developments in this area would result in smaller batteries or less bulky, tethered power supplies. With these smaller batteries, the form factors of devices can radically change, resulting in electrification and increased efficiency across a broader range of vehicles, infrastructure, objects, and devices.

EMERGING PLAYERS

- Stanford University
- Indiana Department of Transportation
- WiBotic
- Electric Sky

1ST YEAR ON THE LIST

Sweat Power



A wearable microgrid uses energy from human sweat and movement to power wearable devices.

Credit: Lu Yin

KEY INSIGHT

We already know sweat can be a valuable input for wearable devices to give users real-time health and wellness information. But sweat might also be able to serve as a biofuel to power those devices.

EXAMPLES

Nanoengineers at the University of California, San Diego are working on a “wearable microgrid” that essentially harvests natural energy directly from the user’s body. The technology gets inspiration from community microgrids. Such microgrids integrate several renewable inputs such as wind and solar power. Researchers envision wearables functioning as personal microgrids, receiving energy from multiple sources, including sweat as a biofuel. The device can generate power even when the wearer is asleep or sitting motionless. Researchers at Nanyang Technological University in Singapore have created their own flexible battery that is also powered by sweat. It could potentially be used to power medical devices and wearables, especially ones that already collect sweat for diagnostic purposes. This could reduce the size of medical wearables, since the batteries in those devices would always be connected to an additional power supply.

DISRUPTIVE IMPACT

Harvesting energy from a user’s body is not necessarily a new concept. Since as early as the 1770s, self-winding watches have employed the natural motion of wearers as a source of power. Other approaches have used light and heat. As wearable devices become more ubiquitous, they will benefit from a personal microgrid of sweat energy to extend the available time of batteries. Medical implantables could also one day benefit from this technology. Some implantables are inhibited by size and space, because they require bulky batteries to keep operating. By adding sweat power, implantables have the ability to be smaller, fitting a broader range of applications.

EMERGING PLAYERS

- University of California, San Diego
- Nanyang Technological University



00

01

02

03

04

05

06

07

08

09

10

11

12

13

Climate, Energy & Space

Space

“

I'm so filled with emotion about what just happened. It's extraordinary, extraordinary. I hope I can maintain what I feel now. I don't want to lose it. It's so much larger than me and life.

— William Shatner, after returning from his Blue Origin spaceflight

”

15TH YEAR ON THE LIST

Space and Off-Planet Exploration



NASA's James Webb Space Telescope is on a quest to collect infrared light from the distant corners of the cosmos.

KEY INSIGHT

Human ambition, the quest for knowledge, and curiosity have always driven the rush to explore space. These factors will continue in 2022, with myriad public and private missions paving the way for humans to revisit the moon and one day visit other celestial bodies.

EXAMPLES

Several noteworthy space-related milestones and events happened last year. As part of the Perseverance Mars mission, NASA's Mars helicopter, Ingenuity, became the first aircraft to perform a powered, controlled flight on another planet. Also part of this mission, The Mars Oxygen In-Situ Resource Utilization Experiment (MOXIE) produced oxygen from carbon dioxide found in Mars' atmosphere. China also successfully landed and deployed the Zhurong rover on the surface of Mars, becoming just the second nation to accomplish this feat. This past year saw a new space race, this time among billionaires rather than governments. Other civilians made history, by becoming the first private crewed mission aboard SpaceX's Dragon capsule as part of the Inspiration4 mission. Russia made headlines when it tested an anti-satellite weapon, intentionally destroying one of its old, Soviet-era satellites and in the process imperiling the lives of astronauts aboard the International Space Station.

DISRUPTIVE IMPACT

The space industry is estimated to be worth \$420 billion, and many of the milestones from the past year could contribute to the industry tripling to a \$1.4 trillion market by the end of the decade. From leisure travel to asteroid mining to telecom, myriad industries and businesses will spring from and benefit from space exploration. The explorations happening today on Mars could create the foundations for future colonization of the planet. However controversial, billionaires self-funding excursions to space could serve as precursors for a growing space tourism industry. The increase in private missions reveals that the future of space could be open to a broader audience than ever before.

EMERGING PLAYERS

- SpaceX
- Blue Origin
- Spaceflight
- Loft Orbital
- Orbit Fab
- Neumann Space
- World View
- LeoLabs
- Orbital Insight
- Rocket Lab
- Astroscale

Commercializing Space



Orbital Reef is the low Earth orbit station designed by Blue Origin (founded by former Amazon CEO Jeff Bezos) and the Sierra Nevada Corporation's Sierra Space for commercial space activities and space tourism uses. Blue Origin has referred to it as a "mixed-use business park."

■ Space Barons

The year 2021 marked a new space race, but rather than being a competition between Cold War adversaries, this one was among some of the world's wealthiest people. Despite the success of various SpaceX initiatives over the years, founder Elon Musk was not the first billionaire in space. Instead, Richard Branson became the first billionaire to travel to low-Earth orbit on July 11, 2021, traveling 50 miles above New Mexico. Jeff Bezos ascended 65 miles above Texas just nine days later. Bezos also made it possible for the 90-year-old actor William Shatner to become the oldest person to travel to space. These acts of affluent space tourism inspired a vigorous public debate: Could such private exploration lead to solving some of the world's biggest challenges, or are we witnessing nothing more than self-indulgent escapades of the super-rich?

■ Certifying Commercial Astronauts

In the U.S., only three agencies confer licenses for astronauts: the FAA, the military, and NASA. While the military and NASA award wings to their own employees, the FAA will soon license commercial astronauts the way they do commercial pilots. To be certified as a commercial astronaut, a person must be employed by a space-related company in advance of their flight. This means those first few Blue Origin launches that took actor William Shatner and former NFL player Michael Strahan off planet didn't result in commercial certifications. Under new FAA guidelines, in order to gain certification, astronauts must complete training, fly higher than 80 kilometers, and demonstrate "activities during flight that were essential to public safety or contributed to human space flight safety." During the next few years, agencies responsible for awarding astronaut wings will need to evolve

their criteria as more people travel off planet on commercial flights.

■ Private Space Stations

Blue Origin, in partnership with Boeing, Sierra Space, and other companies, is developing Orbital Reef, which will become the first privately owned and operated space station. For a fee, governments and other companies could reserve space on Orbital Reef. Tourists could also book reservations to stay on the space outpost. Nanoracks and Lockheed Martin are also building another private station, Starlab, that will host up to four astronauts. And Axiom Space has a station under development. The International Space Station, built in partnership between the U.S., Russia, and other nations, loses its current funding in 2024. While it's likely that a fresh infusion of money will keep the ISS running through 2028, private space stations could prove to be viable alternatives by the end of the 2020s.

Commercializing Space

■ Space Tourism

While not technically qualifying as space tourism, SpaceX's Inspiration4 mission saw a private flight launch four civilians into space. This, along with other private flights by Richard Branson, Jeff Bezos, and William Shatner, paves the way for commercial space flight to become more commonplace, albeit initially reserved for the wealthy. Japanese billionaire Yusaku Maezawa's trip to the International Space Station marks the first self-funded tourism mission to the ISS in nearly a decade. On his 12-day mission, Maezawa will get to experience the marvels of space while being documented by his production assistant and videographer Yozo Hirano. Maezawa has plans to travel alongside eight artists of his choosing to the moon aboard SpaceX's Starship as early as 2023. The first space hotel, Orbital Assembly's Voyager Station, could become accessible as early as 2027.

■ Galactic Ride Sharing

The concept of galactic ridesharing dates back to 2018. Spaceflight Industries (now Spaceflight Inc.) purchased all available payload space on a SpaceX Falcon 9 to serve customers who wanted to launch various items into space. The company is now designing and manufacturing orbital transfer vehicles in a new product line called Sherpa. Spaceflight has produced an orbital transfer vehicle powered by an electric propulsion system called Sherpa-LTE, as well as a chemical-propelled vehicle named Sherpa-LTC1. The latter is headed to space this year to direct 13 customer spacecraft into two separate orbits. Loft Orbital is a San Francisco-based startup also establishing itself in the galactic ridesharing industry. In 2021, the startup launched two microsattellites, YAM-2 and YAM-3, as part of SpaceX's Transporter-2 mission, alongside 10 payloads from government and commercial customers. Loft plans to offer edge

computing as part of its service, allowing onboard computers to process data they collect and perform autonomous decision-making and tasks rather than relying on terrestrial servers. As more researchers, artists, and everyday people want to hitch rides on spacecraft, we anticipate new "rocketsharing" business models—followed by a potential wave of regulation.

■ Space Mining

The prospect of conducting mining operations on asteroids and the moon still seems like science fiction to many—and to be sure, its viability isn't certain. While the economics of mining celestial bodies for export back to Earth might deserve fair criticism, for long-distance space travel and colonization of moons and Mars to work, space mining will be necessary. The moon, meteors, and asteroids promise water and precious rare-earth elements and metals. Mining those minerals in outer space could be

a lucrative venture as well as a cunning geopolitical strategy, because China currently controls 95% of rare-earth element production. Considering how lucrative harvesting these rare-earth elements could be, it's not surprising that companies and government agencies want to pursue the undertaking. According to analysis by *The Planetary Science Journal*, two near-Earth asteroids could contain \$11.65 trillion worth of precious metals. The amount of iron, nickel, and cobalt would exceed what is available on Earth. Farther from Earth, 16 Psyche, an asteroid NASA plans to study in 2022, is estimated to be worth \$10,000 quadrillion in rare-earth elements and other resources, far exceeding the entire net wealth on our planet. If geopolitics does not prevent it, mining the moon will come much sooner than mining asteroids. Mining for lunar water is a potential opportunity to manufacture propellant for return trips to Earth or as a refueling station for spacecraft headed

to more distant destinations. Whether or not celestial mining becomes a viable business practice in the near term, the idea of commercial space exploration puts pressure on governments to create clear international agreements and frameworks for governing space.

Space Politics



China and the U.S. are competing for a space-based strategic advantage.

■ Country-Level Space Initiatives

As of 2022, there are 72 different space agencies in the world. Of those, only 14 have launch capabilities, and an even smaller number, just six, have full launch capabilities. While NASA stands out from the crowd, other agencies have made recent successful launches to Mars. Both China and the United Arab Emirates have conducted missions to the red planet. The Hope Mars Mission is the first unmanned, interplanetary satellite overseen by the UAE. It also is the first planetary science mission conducted by an Arab or Islamic country. The mission has resulted in new observations and insights about Mars' atmosphere and composition. The European Space Agency (ESA) and the Canadian Space Agency are both making contributions to the launch of the James Webb Space Telescope. Applicants overwhelmed the ESA in 2021 when the agency opened applica-

tions for para-astronauts with physical disabilities. While China and Russia collectively have their sights set on the moon, Indian Prime Minister Narendra Modi is pushing to privatize India's highly guarded governmental space agency in hopes to compete again with its global peers.

■ Geopolitics

As countries are mired in geopolitical tensions on Earth, these same tensions will follow them to space. The Artemis Program, which aspires to send the first woman and next man to the moon sometime beyond 2024, has attracted Australia, Canada, Italy, Japan, Luxembourg, the United Arab Emirates, the United Kingdom, Ukraine, South Korea, New Zealand, Brazil, Poland, and Mexico to join forces with the United States under the Artemis Accords. This international agreement for civil exploration and peaceful use of the moon, Mars,

and other astronomical objects faces some criticism. Dmitry Rogozin, the head of Russia's space agency, has called out the Accords as being too U.S. centric. In response, his agency has signed a memorandum of understanding with China's space program to create their own moon operation and build the International Lunar Science Station. The two programs will invite other countries to join the alliance. These tensions among different nations do not come as a surprise. Leaders in space exploration will have access to valuable resources, wield symbolic power, and perhaps even exhibit military domination over other countries.

■ Space Forces

The U.S. announced the launch of a new Space Force in 2019. Its purpose: To secure satellite communication networks that not only power our information ecosystems but also control navigation

Space Politics



The U.S. launched its Space Force in 2020.

and positioning systems. The new service is expected to employ up to 15,000 military personnel and should benefit from former President Trump's signing of a \$738 billion defense bill. The U.S. isn't the only country with a military space program. Both Russia and China maintain their own space forces. It's unlikely that a traditional war would be fought among the stars. This space race is about securing critical network and communications infrastructure from government-sponsored cyberhacking. Since its inception, the U.S. Space Force has launched two experimental satellites to detect nuclear explosions, track space objects as small as baseballs, conduct laser communications trials, and monitor the weather.

■ China's Space Ambitions

China's space program is well underway. It's well-capitalized, includes many space startups, and has the full support

of the government. China is currently in the middle of constructing its space station, Tiangong, or Heavenly Palace. While it won't be fully complete until late 2022, Tiangong has already hosted two separate crews, and it is fast becoming a rival of the International Space Station, which is nearing its planned end-of-life date in 2024. The lunar rover that China sent to the moon in January 2019 has spotted a mysterious cube-like object on the surface of the moon and will launch an investigation into the object. Beyond the moon, China successfully landed its Zhurong rover on the surface of Mars in May 2021, marking the first time the country has landed a rover on another planet, and becoming only the second country to drive a rover on Mars behind the U.S. China intends to send a second lander to Mars by 2028, with the purpose of bringing back samples from the planet's surface. While China is taking strides to

catch up with the U.S. in terms of space exploration, it is also vying with the U.S. in the commercial space industry. China has announced that it has plans to continue its space-born Internet of Things project, unveil a new remote sensing constellation scheme, and continue Kuaizhou, a family of low-cost, solid-fueled carrier rockets intended to launch low-orbit satellites.

■ Space Regulation

With the exception of the Outer Space Treaty in 1967, there has been a lack of significant progress relating to rules and regulations for space. The treaty bans stationing weapons of mass destruction in space, forbids military activities on celestial bodies, and outlines rules relating to the peaceful exploration of space. Nearly 60 years later, diplomats are pressing the issue again, suggesting that the United Nations establish new norms and standards for space.

As nations' space programs grow and become more advanced, some fear that provocations could quickly escalate, especially as military satellites become capable of damaging or interfering with other satellites. The U.S. Space Force is already alleging that Russia and China are attacking its satellites with lasers, radio jammers, and cyberattacks. In November 2021, a United Nations panel resoundingly passed a resolution to approve the working group that will reassess space regulations. If established, this working group would "make recommendations on possible norms, rules, and principles of responsible behaviors relating to threats by states to space systems."

From Such Great Heights

Astronauts who viewed Earth from its orbit described it as a transformative experience: The unique vantage point elicited a more global sense of consciousness, an appreciation and empathy for humankind, and a drive to take action to improve the state of the world.

This life-changing cognitive shift was called the “Overview Effect.”

Artists and philosophers became captivated by the idea, and the term gained traction during the 2010s. Upon return from his trip to space in 2021, billionaire Jeff Bezos talked about the fragility of Earth and a renewed desire to protect it. Other billionaires soon raced to sponsor their own flights to low-Earth orbit in pursuit of the Overview Effect, deluding themselves that they were now one with the planet and humankind—though their actions actually made them even more disconnected from the rest of humanity.

Space tourism startup Crisr Space Technologies launched low-earth orbit trips for anyone wanting to experience the Overview Effect, but

only the wealthy could afford the hefty price tag. New startups emerged to provide simulated experiences to the masses who remain earthbound, through the use of high fidelity optics and fully immersive technology. But the manufactured experience was also expensive and mostly reserved for the affluent.

While the Overview Effect kick-started a collective cognitive shift to address the existential threats facing man and the planet, it also created a caste-like division in society between those who experienced the Overview Effect firsthand, those who experienced it virtually, and those who had not experienced it at all.



Space Sustainability



Sumitomo Forestry and Kyoto University, both based in Japan, are developing degradable satellites made out of wood to cut down on space junk.

■ Space Junk

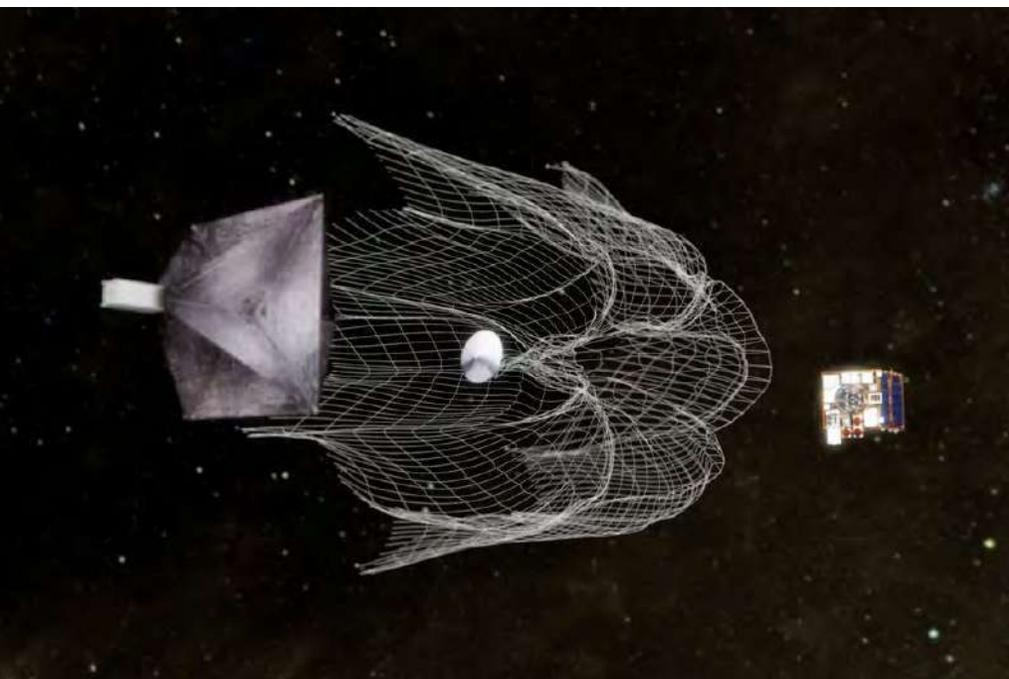
Space has become Earth's dumping ground. As many as 170 million fragments of metal and astro debris orbit the Earth. The debris consists of large components such as used rocket stages, as well as fragments as small as tiny flecks of paint. Traveling at speeds above 16,777 mph, even the smallest of fragments can damage spacecraft. Currently, only 22,000 pieces are tracked, underscoring how much of a threat this floating debris represents. In addition to the risk that space junk poses to space travelers, it poses risks on Earth as well. At least 200 objects fall back into the atmosphere each year, including pieces of solar panels, antennas, and fragments of metal. In space, collisions beget collisions in a chain reaction known as the Kessler syndrome, a phenomenon that could eventually make some available orbits unusable. Some researchers say that the growing amount of debris in

space could result in Earth developing Saturn-like rings composed of junk. Russia recently brought attention to the severity of the issue when it shot down one of its Soviet-era satellites in an attempt to test anti-satellite technology; the incident propelled 1,500 trackable fragments into space, along with hundreds of thousands more that are too small to detect. Astronauts on the International Space Station were forced to board two spacecraft that could return them to Earth if a collision became likely. As we continue to pollute the skies, we could be unintentionally wreaking havoc on civilizations far away from Earth, catalyzing future intergalactic wars. Or we might cause far less scintillating problems. Space junk could start to behave unpredictably, reflecting sunlight in disruptive ways, altering our atmosphere, or even challenging our understanding of the universe and the laws of physics.

■ Space Sustainability Initiatives

Space junk is becoming a bigger problem as more satellites are launched into the atmosphere, but groups are emerging to develop solutions for this evolving problem. In 2021, amid the billionaire space race, Apple co-founder Steve Wozniak cryptically announced his own space program, Privateer, which intends to address the existential threat of space debris by incorporating crowdsourced information along with data collected by its own fleet of satellites. Hopefully, Privateer's plan to release more satellites into low-Earth orbit will not exacerbate the issue. At least 36 other companies want to address the space junk problem, according to SpaceFund. Of those, Astroscale demonstrated its space junk removal system that can capture and deorbit satellites. As landfills on Earth continue to fill up, so too has the orbit surrounding Earth. While we continue to address issues of sustainability on our

Space Sustainability



Scientists have been developing various solutions to space junk, ranging from nets like this trial RemoveDebris mission to solar-powered vacuums.

home planet, we will have to also keep our efforts focused on the skies above.

■ Mercury Rain

New propulsion systems for rocket engines would use mercury as a fuel, which could run the risk of spreading toxic chemicals through Earth's atmosphere. NASA experimented with mercury in the 1960s because it's a low-cost, high-power option for ion engines. Startup Apollo Fusion (acquired by Astra) discovered a new approach to using mercury—but there's a catch. Mercury is heavier than the xenon and krypton powering other ion engines in use today. What customers might save on costs could pollute the atmosphere in potentially harmful ways. While the U.S. government has tried to reduce terrestrial mercury emissions since the 1990s, the rules do not specifically cover spacecraft. The U.S. Federal Aviation Administration requires companies to

disclose hazardous materials in flight, but its policy doesn't address satellites. This is an area where, yet again, technology has sped beyond the limits of the law.

■ Monitoring Climate Change From Space

This year, NASA will launch six small satellites (smallsats) as part of a constellation of smallsats consisting of seven in total. The project, called TROPICS (Time-Resolved Observations of Precipitation structure and storm Intensity with a Constellation of Smallsats), will ultimately improve our understanding of tropical cyclones, which traditionally have been difficult to forecast. The smallsats will be launched in a specific orbital configuration, allowing them to crisscross the equator at different points in order to offer more frequent coverage. Microwave radiometers aboard these units will enable forecasters to see

occurrences that the naked eye cannot. The data will be transmitted to Earth for use in numerical weather prediction models. A test satellite launched in 2021 was able to provide insight into Hurricane Ida. As hurricanes increase due to climate change, this increased data will be invaluable to researchers tracking tropical storms.

Space Innovation



MIT professor Dava Newman models her BioSuit, an innovative upgrade to traditional astronaut suits. The BioSuit is a skintight garment that uses shape-memory nickel-titanium alloy.

Image courtesy: NASA

■ Space Imaging

The successor of NASA's Hubble Space Telescope, the James Webb Space Telescope (JWST), will operate in a fundamentally new way. The Hubble primarily functioned as an optical telescope, capable of detecting light wavelengths similar to those that the human eye can detect. The JWST, on the other hand, will detect near- and mid-infrared light that the human eye cannot see, meaning it will study parts of our universe that are otherwise invisible to humans. Due to this infrared imaging, the JWST will capture light that has been traveling for almost the entire existence of the universe. It will also be able to peer through dust that can obstruct objects in Hubble images. For the infrared light to be captured free of the warmth of Earth, the JWST will operate 1 million miles from our planet. The JWST also features a much bigger mirror that is segmented and foldable and can be covered with a deployable sunshield. Overall, the

JWST is 100 times more powerful than its predecessor. As the JWST advances the imaging we have of space, it could be the device that allows us to discover if there is another planet in the universe similar to our own.

■ Satellite Megaconstellations

According to the Union of Concerned Scientists, there are currently more than 4,550 operational satellites in Earth's orbit, but soon that number could rise substantially. SpaceX's first generation of Starlink alone will put 11,926 new satellites into orbit, while the second generation will launch an additional 30,000. In 2022, Amazon will prototype its Project Kuiper broadband constellation, sending KuiperSat-1 and KuiperSat-2 to deploy the prototypes into low-Earth orbit. If successful, the project could result in an additional 3,200 satellites in orbit. OneWeb and China's SatNet could combine for an additional 15,000 satellites deployed.

These satellite constellations comprise many small "microsats" or "cubesats," which are capable of communicating with each other and continue to work when one satellite in the network goes down. Constellations are used for a variety of purposes, including taking photos and beaming internet access back down to Earth. But with thousands of planned spacecraft launches—carrying microsats and cubesat constellations, in addition to heavier satellites, rockets, and spacecrafts with rovers and human cargo—astronomers are warning that our view of the sky, and our ability to research the cosmos, is in jeopardy. Scientists have voiced concern that megaconstellations of microsats and cubesats will not only obstruct their view but that they could also interfere with radio astronomy equipment. Astronomers are proposing establishing a "SatHub" to address the threats of megaconstellations. It would monitor new satellites that go up and perform training, outreach, and analy-

Space Innovation

sis of satellites for the broader astronomy community.

■ Self-Steering Satellites

Researchers at the U.S. Naval Research Laboratory are working on a concept that could not only help steer satellites back down to Earth when they're decommissioned but also clean up space clutter in the process. The idea is to outfit new satellites with thin "umbilical cords" about a kilometer long. Running an electric current through the cord would enable a satellite to steer itself using its own electric field as well as Earth's magnetic field. Think of it as an invisible sail that could someday enable old satellites to guide themselves home.

■ Galactic Refueling Stations

Satellites often outlive their expected service lives, but the limited amount of fuel they can carry often leads to the cessation of their services. To address

the problem of abandoned satellites from lack of fuel, the startup Orbit Fab has produced what it calls the Rapidly Attachable Fluid Transfer Interface (RAFTI), which is basically a fueling port that will allow satellites to be refueled from space. To help establish orbital refueling services, Lockheed Martin began investing in Orbit Fab's project. The RAFTI system aims eventually to allow more satellites to stay in orbit and help reduce the creation of new space junk. Meanwhile, the Australian company Neumann Space has created an in-space electric propulsion system that can be used to move satellites within low-Earth orbit. Significantly, the system is powered by metal rods that could be fabricated from space debris. One day, it might be possible for a satellite to collect debris, melt it and shape it into metal rods, and then use those rods to propel itself through low-Earth orbit.

■ Off-Planet Living

Efforts to colonize space have become more pronounced as both governmental agencies and private organizations have adopted grand ambitions for establishing life beyond Earth. Jeff Bezos believes in the prospect of space colonization to the degree that he thinks most people centuries from now will be born in space and could visit Earth, which will be something like a protected national park. In 2021, Elon Musk became a renter after selling his last house on Earth, possibly signaling his long-term goal of building colonies of 1 million inhabitants on Mars by 2050. NASA has its own ambitions to send humans to Mars. From the agency's continuous presence on the ISS for 20 years, it knows firsthand that any dwelling in space must be able to protect astronauts from extreme temperatures and radiation. In 2016, NASA selected six private U.S. companies—including

Boeing, Lockheed Martin, and Bigelow Aerospace—to develop prototypes for deep-space habitats. Since then, NASA has formulated additional plans for building habitats for space. A research team at NASA Ames Research Center is looking at mushrooms as a possible building material, taking inspiration from "mycotecture" (a portmanteau of mycology and architecture). Building materials crafted from reishi mushrooms can bear thousands of pounds per square inch and can serve as storage batteries due to their number of carbon fibers. What's more, transporting spores of these mushrooms to space would be cost-effective. As more interest turns toward space colonization, radical ideas such as mycotecture will become more of a reality.

■ Ultra-Long Space Missions

If climate change escalates and we are unable to mitigate its effects, humanity is going to need a plan B. Some sci-

entists think our next best option is a 1,000-year space mission to save future generations from extinction. Their target is a planet called Proxima Centauri b, an exoplanet in a habitable zone of a star like our sun. This means that water might exist in liquid form there and, theoretically, could support human life. We don't know what the atmosphere is like or whether the planet's surface is too hot or cold to sustain living organisms as we know them. A program founded by science philanthropist Yuri Milner and the late Stephen Hawking is building a spacecraft weighing only a few grams that would be propelled by a 100-billion-watt laser fired at it from Earth. The craft would take 20 years to reach the Alpha Centauri solar system, where Proxima b is located. It's a step toward building a new kind of spacecraft big enough to transport humans deep into space on a journey that would take a millennium to reach humanity's new home.

Space Innovation



NASA has begun testing space habitation prototypes.

Image courtesy: NASA

■ Aerial and Oceanic Exploration of Other Planets

NASA's Perseverance had a Wright brothers experience when the aircraft Ingenuity performed the first powered, controlled flight on another planet. Beyond Ingenuity, we will see an expansion of aerial exploration of other planets and hence greater coverage and efficiency of such missions. NASA's Dragonfly mission, for example, will use rotorcraft to search Saturn's moon Titan for "the building blocks of life." Additionally, NASA's SESAME initiative will emphasize ocean exploration on distant moons in the coming decade. To accomplish this, the agency is looking into 3D printing "micro-swimmers," tiny wireless devices controlled with ultrasound waves that can be used to sample faraway ocean floors.

■ Space Cuisine

With emphasis on colonizing Mars, scientists know that four of the five

major consumable resources, including energy, water, oxygen, and construction materials, are potentially abundant on the planet. Food is not, and it will prove to be the hardest thing to produce locally on Mars. To creatively address this, NASA and the Canadian Space Agency have issued the Deep Space Food Challenge. To advance in the challenge, entrants must be able to offer a food solution that can feed a minimum of four astronauts on a three-year mission. The challenge has already advanced beyond the first phase with winners using 3D printers, bioreactors, and vertical farming as possible solutions for growing food in space. Private organizations also want to capitalize on the opportunity to bring food to Mars. Budweiser has the ambitious goal of being the first beer served on Mars. In preparation, the company has been sending barley seeds to the International Space Station since 2017, with plans to experiment with malting in space. Heinz also has lofty ambitions. The company has

successfully grown tomatoes in Mars-like conditions and soil, to make "Marz Edition" ketchup.

■ Scaling the Overview Effect

The Overview Effect is the cognitive shift in awareness that astronauts report experiencing after they view Earth from orbit or from the moon. This perception of the world had a profound impact on Frank White, who coined the term, stating, "You develop an instant global consciousness, a people orientation, an intense dissatisfaction with the state of the world, and a compulsion to do something about it." Both Jeff Bezos and William Shatner reported having similar sensations after their respective rides to low-Earth orbit. It is only a matter of time until this phenomenon is successfully reproduced digitally, or leads to a new form of space tourism.

Beyond Earth/Beyond Human · Far-future pessimistic scenario

By 2070, climate change has ravaged the earth. Mitigation strategies pursued decades earlier did not prevent the worst outcomes, but they did delay the inevitable destruction. By 2040, governments across the globe concluded climate change had reached the point of no return. They began a global collaboration to prepare the world's population for space travel.

While highly controversial, scientists pursued the necessary gene editing experiments. Volunteers underwent experimental procedures to acclimate the human body for life on other planets. Early edits aimed to make humans resistant to radiation, to counteract the deleterious effects of zero gravity, making them more durable for long-distance space travel. Controversy increased upon the discovery that those who received the gene edits wouldn't venture off the planet, but rather were expected to create offspring that were space ready. An entire generation was unwittingly volunteered for emergency missions, and many began to wonder if they were truly human, or if they had evolved beyond humanity.

The global coalition began long-distance missions in 2065 in search for habitable exoplanets. Years later, most of these missions had not yet found a suitable planet for habitation. For them, hope of survival relied on additional procedures to grow synthetically engineered organs to replace those that had failed. These advanced organs raised additional existential questions for these individuals about their human identity. But as they traveled further into the depths of space, it became clear that they would soon be the only remaining representatives of Earth.

DOWNLOAD...

FX-851

SCREEN_28





This we know; The earth does not belong to man; man belongs to the earth. This we know, all things are connected like the blood which unites one family. All things are connected.

— Chief Si'ahl, Namesake of the City of Seattle



How these trends impact your company



STRATEGY

Throughout every industry, climate change and sustainability have taken center stage. With the passage of green stimulus plans and the growing popularity of environmental, social, and corporate governance (ESG) initiatives, there will be new incentives to measure energy usage, sustainability criteria, and environmental impacts. We anticipate new opportunities for companies that strategically map the next two to five years with sustainability and ESGs in mind. Conversely, companies that wait could find themselves regulated in new ways or facing financial penalties. First movers and fast followers could help shape the directions of their industries, which would be a long-term strategic advantage.



INNOVATION

Senior executives are prioritizing sustainability broadly across their organizations. Likewise, consumers are asking that sustainability concepts are factored into product development. But some organizations or business units see sustainability as a risk, an added expense, or a challenge to existing operations. This presents a unique opportunity for innovation teams, which can resolve those fears with new workflows, products, and services.



R & D

There has never been a better time to pursue R&D in energy, sustainability, and space initiatives. With investment pouring into these areas and regulation creating a sense of urgency, this is a good time to develop moonshot ideas and develop the workflows to match. The biggest challenge: which big bets to place.



GROWTH

Climate change, extreme weather events, and an uncertain regulatory landscape will impact growth in some businesses. Scenario planning is critically important in 2022 and beyond. Teams should actively rehearse alternative futures, including financial models and contingency plans to mitigate supply chain disruptions, geopolitical tensions, and sustained changes in consumer behavior.

Key Questions

We recommend using this report to support your strategic foresight activity in the coming year. Every executive team should begin by asking these questions:

1

- ▶ How could climate change disrupt our business in the next decade?

- ▶ If we expand our view very broadly, in what ways are we vulnerable to extreme weather events, new human migration patterns, transportation delays, supply chain disruptions, and new sustainability-related regulations in the markets where we operate?

2

- ▶ Where does the nascent space economy represent new growth opportunities for our business?

- ▶ How can we participate in the emerging space economy 10 years from now—even if our business is unrelated to space today?

3

- ▶ What assumptions must hold true for our current strategy to succeed, given uncertainty brought by climate change, sustainability initiatives, energy production, and space commercialization?

Selected Sources

"5 European Companies Helping to Clean up the Oceans." Accessed January 11, 2022. <https://www.aquat-echtrade.com/news/water-treatment/5-companies-helping-to-clean-up-the-oceans/>.

"6 Products Made From CO2 Removed from the Atmosphere ~," April 17, 2021. <https://bylaurelchristine.com/products-made-from-co2/>.

"7-Eleven to Install 500 EV Charging Ports by the End of 2022 | TechCrunch." Accessed January 11, 2022. <https://techcrunch.com/2021/06/01/7-eleven-to-install-500-ev-charging-stations-by-the-end-of-2022/>

"A Company Is Producing Thousands of Cheap, Floating Nuclear Reactors." Accessed January 11, 2022. <https://interestingengineering.com/seaborg-producing-thousands-cheap-floating-nuclear-reactors?>

NBC News. "A Good Time to Live on the Ocean? 'Seasteaders' Double down during Pandemic." Accessed January

11, 2022. <https://www.nbcnews.com/tech/tech-news/good-time-live-ocean-seasteaders-double-down-during-pandemic-n1231293>.

"A Massachusetts Company Leads as the Race for Fusion Energy Heats Up." Accessed December 2, 2021. <https://www.wbur.org/news/2021/12/02/massachusetts-fusion-power>.

TechCrunch. "A Step Forward for CO2 Capture." Accessed January 11, 2022. <https://social.techcrunch.com/2021/12/03/co2-capture-ice-land-climeworks-orca/>.

EurekAlert! "A Sun Reflector for Earth?" Accessed January 11, 2022. <https://www.eurekalert.org/news-releases/654978>.

Fusion Industry Assn. "About the Fusion Industry | Commercializing Fusion Energy." Accessed January 11, 2022. <https://www.fusionindustryassociation.org/about-fusion-industry>.

Access, The Space Weather Modeling Framework Goes Open. "Supercom-

puter Helps Protect Earth From Space Storms." SciTechDaily (blog), August 18, 2021. <https://scitechdaily.com/super-computer-helps-protect-earth-from-space-storms/amp/>.

Acovino, Vincent. "The Biggest Problem Facing the U.S. Electric Grid Isn't Demand. It's Climate Change." NPR, November 24, 2021, sec. Energy. <https://www.npr.org/2021/11/24/1040529860/the-biggest-problem-facing-the-u-s-electric-grid-isnt-demand-its-climate-change>.

Air Company. "Air Company." Accessed January 11, 2022. <https://aircompany.com/>.

Ambrose, Jillian, and Jillian Ambrose Energy correspondent. "Government Reveals Plans for £4bn Hydrogen Investment by 2030." The Guardian, August 16, 2021, sec. Environment. <https://www.theguardian.com/environment/2021/aug/17/uk-homes-low-carbon-hydrogen-economy-jobs>.

April 27th 2021, Matt Simon | News |. "Plastic Rain Is Falling from the

Sky. But Where's It Coming From?" Canada's National Observer, April 27, 2021. <https://www.nationalobserver.com/2021/04/27/news/plastic-rain-falling-sky-microplastics-pollution>.

Aeon. "Asteroid Mining Could Pay for Space Exploration and Adventure | Aeon Essays." Accessed January 11, 2022. <https://aeon.co/essays/asteroid-mining-could-pay-for-space-exploration-and-adventure>.

"Australia Launches \$738m Fund to Support Green Tech." Accessed January 11, 2022. <https://www.aljazeera.com/economy/2021/11/10/australia-launches-738m-fund-to-support-green-tech>.

Ball, Philip. "The Chase for Fusion Energy." Accessed January 11, 2022. <https://www.nature.com/immersive/d41586-021-03401-w/index.html>.

"Batteries Made from Trees Could Help Transform the Future of Electric Travel | Euronews." Accessed January 11, 2022. [from-trees-could-help-transform-the-future-of-electric-travel?.](https://www.euronews.com/green/2021/08/10/batteries-made-</p>
</div>
<div data-bbox=)

"Battery Market Size Worth \$310.8 Billion By 2027." Accessed January 11, 2022. <https://www.grandviewresearch.com/press-release/global-battery-market>.

electrive.com. "Battery Research Project Takes off in Canada," June 4, 2021. <https://www.electrive.com/2021/06/04/battery-research-project-takes-off-in-canada/>.

BRINK – Conversations and Insights on Global Business. "Battery Technology Is About to Disrupt the US Power Sector." Accessed January 11, 2022. <https://www.brinknews.com/battery-technology-is-about-to-disrupt-the-us-power-sector/>.

Berger, Eric. "NASA Sets Sail into a Promising but Perilous Future of Private Space Stations." Ars Technica, December 3, 2021. <https://arstechnica.com/science/2021/12/nasa-sets-sail-into-a-promising-but-perilous-future-of-private-space-stations/>.

Selected Sources

"Bill Gates-Backed Startup to Build 'turquoise Hydrogen' Pilot by End of 2022." Accessed January 11, 2022. <https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/bill-gates-backed-startup-to-build-turquoise-hydrogen-pilot-by-end-of-2022-65354106>.

Brahney, Janice, Natalie Mahowald, Marje Prank, Gavin Cornwell, Zbigniew Klimont, Hitoshi Matsui, and Kimberly Ann Prather. "Constraining the Atmospheric Limb of the Plastic Cycle." Proceedings of the National Academy of Sciences 118, no. 16 (April 20, 2021). <https://doi.org/10.1073/pnas.2020719118>.

Brannen, Peter. "The Anthropocene Is a Joke." The Atlantic, August 13, 2019. <https://www.theatlantic.com/science/archive/2019/08/arrogance-anthropocene/595795/>.

"Busan, UN-Habitat and OCEANIX Set to Build the World's First Sustainable Floating City Prototype as Sea Levels Rise | UN-Habitat." Accessed January 11, 2022. <https://unhabitat.org/busan-un-habitat-and-oceanix-set-to-build-the-worlds-first-sustainable-floating-city-prototype-as-sea-levels-rise>.

habitat-and-oceanix-set-to-build-the-worlds-first-sustainable-floating-city-prototype-as.

Bushwick, Sophie. "This Room Could Wirelessly Charge All Your Devices." Scientific American. Accessed January 11, 2022. <https://www.scientificamerican.com/article/this-room-could-wirelessly-charge-all-your-devices/>.

Business, Jackie Wattles, CNN. "First Space Station Tourist in Ten Years Docks at ISS." CNN. Accessed January 11, 2022. <https://www.cnn.com/2021/12/07/tech/space-tourism-maezawa-soyuz-scn/index.html>.

Calma, Justine. "Biden Administration Gives Offshore Wind Farms a Big Boost." The Verge, October 13, 2021. <https://www.theverge.com/2021/10/13/22725234/biden-offshore-wind-boost-united-states-coastlines>.

"Extreme Heat Is a Growing Concern for Doctors around the World." The Verge, October 20, 2021. <https://www.theverge.com/2021/10/20/22737250/extreme-heat-health-climate-change-doctors-lancet-report>.

extreme-heat-health-climate-change-doctors-lancet-report.

Science Friday, "Can Genetic Engineering Help Humans Live In Space?" Accessed January 11, 2022. <https://www.sciencefriday.com/segments/human-engineering-space/>.

IEA. "Carbon Capture in 2021: Off and Running or Another False Start? – Analysis." Accessed January 11, 2022. <https://www.iea.org/commentaries/carbon-capture-in-2021-off-and-running-or-another-false-start>.

twelve. "Carbon Transformation." Accessed January 11, 2022. <https://www.twelve.co/>.

Carpenter, Scott. "The Race To Develop Plastic-Eating Bacteria." Forbes. Accessed January 11, 2022. <https://www.forbes.com/sites/scottcarpenter/2021/03/10/the-race-to-develop-plastic-eating-bacteria/>.

Futurity. "Charging Room Delivers Power without Plugs and Wires," August 30, 2021. <https://www.futurity.org/charging-room-wireless-electricity-power-2619972/>.

charging-room-wireless-electricity-power-2619972/.

Environment + Energy Leader. "Chief Heat Officer to Deal with Effects of Climate Change," June 11, 2021. <https://www.environmentalleader.com/2021/06/miami-appoints-chief-heat-officer-to-address-climate-impacts/>.

Rhodium Group. "Clean Hydrogen: A Versatile Tool for Decarbonization." Accessed January 11, 2022. <https://rhg.com/research/clean-hydrogen-decarbonization/>.

"Clean Hydrogen Emerging As Major Player In Energy Transition." Accessed January 11, 2022. <https://www.forbes.com/sites/uhenergy/2021/11/01/clean-hydrogen-emerging-as-major-player-in-energy-transition/>.

Clement, Viviane, Kanta Kumari Rigaud, Alex de Sherbinin, Bryan Jones, Susana Adamo, Jacob Schewe, Nian Sadiq, and Elham Shabahat. "Groundswell Part 2: Acting on Internal Climate Migration." Washington, DC: World

Bank, September 13, 2021. <https://openknowledge.worldbank.org/handle/10986/36248>.

Clendaniel, Morgan. "Will Consumers Use Products Made from Captured CO2?" Fast Company, May 14, 2021. <https://www.fastcompany.com/90637001/will-consumers-use-products-made-from-captured-co2>.

World Economic Forum. "Climate Refugees – the World's Forgotten Victims." Accessed January 11, 2022. <https://www.weforum.org/agenda/2021/06/climate-refugees-the-world-s-forgotten-victims/>.

ReliefWeb. "Climate Refugees Are Increasingly Victims of Exploitation - World." Accessed January 11, 2022. <https://reliefweb.int/report/world/climate-refugees-are-increasingly-victims-exploitation>.

"Climate Strategies & Targets." Accessed January 11, 2022. https://ec.europa.eu/clima/eu-action/climate-strategies-targets_en.

Selected Sources

CNN, John Keefe and Rachel Ramirez. "Our Underwater Future: What Sea Level Rise Will Look like around the Globe." CNN. Accessed January 11, 2022. <https://www.cnn.com/2021/10/12/world/3-degrees-sea-level-rise-climate-central/index.html>.

Cohen, Ariel. "A Bill Gates Venture Aims To Spray Dust Into The Atmosphere To Block The Sun. What Could Go Wrong?" Forbes. Accessed January 11, 2022. <https://www.forbes.com/sites/arielcohen/2021/01/11/bill-gates-backed-climate-solution-gains-traction-but-concerns-linger/>.

Company, Southern California Gas. "SoCalGas to Fund Testing of First-of-Its-Kind Direct Air Capture Technology." Accessed January 11, 2022. <https://www.prnewswire.com/news-releases/socalgas-to-fund-testing-of-first-of-its-kind-direct-air-capture-technology-301425885.html>.

"Constraining the Atmospheric Limb of the Plastic Cycle | PNAS." Accessed January 11, 2022. <https://www.pnas.org/content/118/16/e2020719118>

UNEP. "COP26 Ends with Agreement but Falls Short on Climate Action," November 15, 2021. <http://www.unep.org/news-and-stories/story/cop26-ends-agreement-falls-short-climate-action>.

"Could Plastic-Eating Microbes Take a Bite out of the Recycling Problem?" Accessed January 11, 2022. <https://www.science.org/content/article/could-plastic-eating-microbes-take-bite-out-recycling-problem>.

IEA. "DAC 1 – CCUS around the World – Analysis." Accessed January 11, 2022. <https://www.iea.org/reports/ccus-around-the-world/dac-1>.

ICOS. "Data Supplement to the Global Carbon Budget 2021." Accessed January 11, 2022. <https://www.icos-cp.eu/science-and-impact/global-carbon-budget/2021>.

Energy.gov. "DOE Announces \$209 Million for Electric Vehicles Battery Research." Accessed January 11, 2022. <https://www.energy.gov/articles/doe-announces-209-million-electric-vehicles-battery-research>.

Energy.gov. "DOE Invests \$45 Million to Decarbonize the Natural Gas Power and Industrial Sectors Using Carbon Capture and Storage." Accessed January 11, 2022. <https://www.energy.gov/articles/doe-invests-45-million-decarbonize-natural-gas-power-and-industrial-sectors-using-carbon>.

Doll, Scooter. "World's First Autonomous, 7MWh Electric Cargo Ship to Make Voyage with Zero Crew Onboard." Electrek (blog), August 25, 2021. <https://electrek.co/2021/08/25/worlds-first-autonomous-7mwh-electric-cargo-ship-to-make-voyage-with-zero-crew-onboard/>.

Gizmodo. "Dubai Is Creating Artificial Rainstorms With Drones." Accessed January 11, 2022. <https://gizmodo.com/the-united-arab-emirates-is-creating-artificial-rainsto-1847351652>.

"Electric Sky Developing New Self-Focusing Beam With DARPA Funding | Aerospace Tech Review." Accessed January 11, 2022. <https://www.aerospacetechreview.com/electric-sky-developing-new-self-focusing-beam-with-darpa-funding/>.

[with-darpa-funding/](#).

"Electric Vehicles Could Fully Recharge in under 5 Minutes with New Charging Station Cable Design - Purdue University News." Accessed January 11, 2022. <https://www.purdue.edu/newsroom/releases/2021/Q4/electric-vehicles-could-fully-recharge-in-under-5-minutes-with-new-charging-station-cable-design.html>

"Electrify America Chargers: EV Charging Network to Double." Accessed January 11, 2022. <https://www.usatoday.com/story/money/cars/2021/07/13/electrify-america-chargers-ev-charging-electric-vehicles-cars/7950468002/?>

Elmhirst, Sophie. "The Disastrous Voyage of Satoshi, the World's First Cryptocurrency Cruise Ship." The Guardian, September 7, 2021, sec. News. <https://www.theguardian.com/news/2021/sep/07/disastrous-voyage-satoshi-cryptocurrency-cruise-ship-seasteading>.

InvestmentNews. "ESG Assets Expect-

ed to Top \$53 Trillion by 2022: Celent," September 15, 2020. <https://www.investmentnews.com/esg-assets-2022-celent-197155>.

Thomson Reuters Tax & Accounting News. "ESG Reporting Is All the Rage, but Companies Are Unsure About Which Reporting Standards to Use," July 20, 2020. <https://tax.thomsonreuters.com/news/esg-reporting-is-all-the-rage-but-companies-are-unsure-about-which-reporting-standards-to-use/>.

"EU Unveils Sweeping Climate Change Plan." BBC News, July 14, 2021, sec. Europe. <https://www.bbc.com/news/world-europe-57833807>.

Gizmodo. "Extreme Heat Will Make Parts of the Middle East and Africa Uninhabitable by 2050." Accessed January 11, 2022. <https://gizmodo.com/extreme-heat-will-make-parts-of-the-middle-east-and-afr-1774311994>.

The White House. "FACT SHEET: President Biden Sets 2030 Greenhouse Gas Pollution Reduction Target

Selected Sources

Aimed at Creating Good-Paying Union Jobs and Securing U.S. Leadership on Clean Energy Technologies," April 22, 2021. <https://www.whitehouse.gov/briefing-room/statements-releases/2021/04/22/fact-sheet-president-biden-sets-2030-greenhouse-gas-pollution-reduction-target-aimed-at-creating-good-paying-union-jobs-and-securing-u-s-leadership-on-clean-energy-technologies/>.

Fellows, University of Houston Energy. "Clean Hydrogen Emerging As Major Player In Energy Transition." Forbes. Accessed January 11, 2022. <https://www.forbes.com/sites/uhenergy/2021/11/01/clean-hydrogen-emerging-as-major-player-in-energy-transition/>.

"Ford, Redwood Materials Teaming Up on Closed-Loop Battery Recycling, U.S. Supply Chain | Ford Media Center." Accessed January 11, 2022. <https://media.ford.com/content/fordmedia/fna/us/en/news/2021/09/22/ford-redwood-materials-battery-recycling.html?>

Frangoul, Anmar. "Green Hydrogen

Hub Backed by \$5 Billion of Investment Planned for the UAE." CNBC, December 7, 2021. <https://www.cnbc.com/2021/12/07/engie-masdar-establish-5-billion-green-hydrogen-alliance.html>.

Earth911. "From Pollutant to Product: Consumer Goods From Captured Carbon," November 29, 2021. <https://earth911.com/eco-tech/consumer-goods-from-atmospheric-carbon/>.

Culham Centre for Fusion Energy. "Fusion in Brief." Accessed January 11, 2022. <https://ccfe.ukaea.uk/fusion-energy/fusion-in-brief/>.

"General Fusion Lands \$130M from Bezos and Others as Fusion Energy Sector Keeps Heating up - GeekWire." Accessed January 11, 2022. <https://www.geekwire.com/2021/general-fusion-lands-130m-from-bezos-and-others-as-fusion-energy-sector-keeps-heating-up/>

"Germany Floods Were up to 9 Times More Likely Because of Climate Change, Study Estimates - CNN." Ac-

cessed January 11, 2022. <https://www.cnn.com/2021/08/23/europe/germany-floods-belgium-climate-change-intl/index.html>

Gilbert, Alex. "Mining in Space Is Coming." Milken Institute Review. Accessed January 11, 2022. <https://www.milkenreview.org/articles/mining-in-space-is-coming>.

UMaine News. "Gill Co-Authors Report Arguing Anthropocene Should Be a Geological Event, Not an Epoch - UMaine News - University of Maine," November 16, 2021. <https://umaine.edu/news/blog/2021/11/16/gill-co-authors-report-arguing-anthropocene-should-be-a-geological-event-not-an-epoch/>.

Bank of America Private Bank. "Green Hydrogen: What Is Green Hydrogen & Why Is It Important." Accessed January 11, 2022. <https://www.privatebank.bankofamerica.com/articles/green-hydrogen-market-importance.html>.

Greenfieldboyce, Nell. "NASA Is Launching A New Telescope That Could Offer Some Cosmic Eye Candy," NPR, Sep-

tember 16, 2021, sec. Science. <https://www.npr.org/2021/09/16/1036600340/nasa-is-launching-a-new-telescope-that-could-offer-some-cosmic-eye-candy>.

Group, BMO Financial. "BMO First Bank to Pre-Purchase Direct Air Capture Carbon Removals Using Carbon Engineering Technology." Accessed January 11, 2022. <https://www.prnewswire.com/news-releases/bmo-first-bank-to-pre-purchase-direct-air-capture-carbon-removals-using-carbon-engineering-technology-301431782.html>.

Grush, Loren. "Head of Russian Space Program Calls for More International Cooperation in NASA's Moon Plans." The Verge, October 12, 2020. <https://www.theverge.com/2020/10/12/21512712/nasa-roscosmos-russia-dmitry-rogozin-artemis-moon-international-cooperation>.

"Visualizations Show the Extensive Cloud of Debris Russia's Anti-Satellite Test Created." The Verge, November 19, 2021. <https://www>.

theverge.com/2021/11/19/22791176/russia-asat-satellite-test-space-debris-visualizations.

Hall, Loura. "Mycotecture Off Planet." Text. NASA, April 7, 2021. http://www.nasa.gov/directorates/spacetech/niac/2021_Phase_I/Mycotecture_Off_Planet.

Hanley, Steve. "New EU Hydrogen Policy: The Good, The Bad, & The Expensive." CleanTechnica, December 6, 2021. <https://cleantechnica.com/2021/12/06/new-eu-hydrogen-policy-the-good-the-bad-the-expensive/>.

Heilweil, Rebecca. "The Space Debris Problem Is Getting Dangerous." Vox, November 16, 2021. <https://www.vox.com/recode/2021/11/16/22785425/international-space-station-russia-missile-test-debris>.

Hooijer, A., and R. Vernimmen. "Global LiDAR Land Elevation Data Reveal Greatest Sea-Level Rise Vulnerability in the Tropics." Nature Communications 12, no. 1 (June 29, 2021): 3592. <https://>

Selected Sources

doi.org/10.1038/s41467-021-23810-9.

“How Climate Change Impacts Refugees and Displaced Communities.” Accessed January 11, 2022. <https://www.unrefugees.org/news/how-climate-change-impacts-refugees-and-displaced-communities/>

Huet, Natalie. “What’s in France’s New Climate Law and Is It Green Enough?” *euronews*, July 20, 2021. <https://www.euronews.com/green/2021/07/20/france-s-new-climate-law-has-just-been-approved-so-why-are-activists-so-unimpressed>.

“Hydrogen Production Costs to 2040: Is a Tipping Point on the Horizon?” | Wood Mackenzie.” Accessed January 11, 2022. <https://www.woodmac.com/our-expertise/focus/transition/hydrogen-production-costs-to-2040-is-a-tipping-point-on-the-horizon/>

Hyun-su, Yim. “Floating Solar Power to Quadruple by 2025: Report.” *The Korea Herald*, August 22, 2021. <http://www.koreaherald.com/view.php?ud=20210822000168>.

“INEOS Announces over €2 Billion Investment in Green Hydrogen Production” INEOS Announces over €2 Billion Investment in Green Hydrogen Production.” Accessed January 11, 2022. <https://www.ineos.com/news/ineos-group/ineos-announces-over-2-billion-investment-in-green-hydrogen-production/>.

Keith, Ladd, Sara Meerow, David M. Hondula, V. Kelly Turner, and James C. Arnott. “Deploy Heat Officers, Policies and Metrics.” *Nature* 598, no. 7879 (October 2021): 29–31. <https://doi.org/10.1038/d41586-021-02677-2>.

Klump, Carlos Anchondo, Edward. “CO₂-Free Natural Gas? CCS Project Powers Grid for First Time.” *E&E News*, November 17, 2021. <https://www.eenews.net/articles/co2-free-natural-gas-ccs-project-powers-grid-for-first-time/>.

Koren, Marina. “Why Is NASA Sending Its New Telescope a Million Miles Away?” *The Atlantic*, December 10, 2021. <https://www.theatlantic.com/science/archive/2021/12/james-webb-space->

telescope-lagrange-point/620935/

Lanzatech, Published 5 Months Ago About a 3 Minute Read Image: “LanzaTech, Lululemon Partner to Create First Fabric Made from Recycled Carbon Emissions.” *Sustainable Brands*, July 13, 2021. <https://sustainablebrands.com/read/product-service-design-innovation/lanzatech-lululemon-partner-to-create-first-fabric-made-from-recycled-carbon-emissions>.

Lavelle, Moira. “By 2050, 200 Million Climate Refugees May Have Fled Their Homes. But International Laws Offer Them Little Protection.” *Inside Climate News* (blog), November 2, 2021. <https://insideclimatenews.org/news/02112021/climate-refugees-international-law-cop26/>.

Lin, Connie. “Marine Life Thrives on the Great Pacific Garbage Patch, Scientists Find.” *Fast Company*, December 3, 2021. <https://www.fastcompany.com/90703031/marine-life-thrives-on-floating-garbage-patches-scientists-find>.

Loeffler, John. “Apple Co-Founder Steve Wozniak Announces Private Space Venture ‘Unlike the Others.’” *TechRadar*. Accessed January 11, 2022. <https://www.techradar.com/news/apple-co-founder-steve-wozniak-announces-private-space-venture-unlike-the-others>.

Mackenzie, Wood. “Hydrogen Production Costs to 2040: Is a Tipping Point on the Horizon?,” August 20, 2020. <https://www.woodmac.com/our-expertise/focus/transition/hydrogen-production-costs-to-2040-is-a-tipping-point-on-the-horizon/>.

Magazine, Smithsonian, and Corryn Wetzel. “This New Installation Pulled 20,000 Pounds of Plastic From the Great Pacific Garbage Patch.” *Smithsonian Magazine*. Accessed January 11, 2022. <https://www.smithsonianmag.com/smart-news/this-new-installation-just-pulled-20000-pounds-of-plastic-from-the-great-pacific-garbage-patch-180978895/>.

“Magnets, Vacuums and Tiny Nets: The New Fight against Microplastics | Plas-

tics | *The Guardian*.” Accessed January 11, 2022. <https://www.theguardian.com/environment/2021/feb/18/microplastics-oceans-environment-science?>

ScienceDaily. “Making Clean Hydrogen Is Hard, but Researchers Just Solved a Major Hurdle.” Accessed January 11, 2022. <https://www.sciencedaily.com/releases/2021/07/210719143405.htm>.

“Manchester, University of. “Plastic-Eating Bacteria Could Help Aid Global Recycling Efforts.” Accessed January 11, 2022. <https://phys.org/news/2021-10-plastic-eating-bacteria-aid-global-recycling.html>.

Marshall, Aarian. “Biden Wants More EVs on Roads. What About Charging Stations?” *Wired*. Accessed January 11, 2022. <https://www.wired.com/story/biden-wants-more-evs-charging-stations/>.

Matei, Adrienne. “Magnets, Vacuums and Tiny Nets: The New Fight against Microplastics.” *The Guardian*, February 18, 2021, sec. Global. <https://www.theguardian.com/environment/2021/>

Selected Sources

feb/18/microplastics-oceans-environment-science.

Mendoza-Moyers, Diego. "S.A.-Based EnCap Flatrock Bets on Carbon Capture Technology." San Antonio Express-News, December 6, 2021. <https://www.expressnews.com/business/article/San-Antonio-based-EnCap-Flatrock-16680398.php>.

MIT News | Massachusetts Institute of Technology. "MIT-Designed Project Achieves Major Advance toward Fusion Energy." Accessed January 11, 2022. <https://news.mit.edu/2021/MIT-CFS-major-advance-toward-fusion-energy-0908>.

"MIT-Designed Project Achieves Major Advance toward Fusion Energy | MIT News | Massachusetts Institute of Technology." Accessed January 11, 2022. <https://news.mit.edu/2021/MIT-CFS-major-advance-toward-fusion-energy-0908>

"Molecular Coffee Scoring Interest from Investors." Accessed January 11, 2022. <https://www.triplepundit.com/>

story/2021/molecular-coffee-investors/727986.

"More Money Than Ever Is Flowing Into Climate Tech." Bloomberg.Com, July 29, 2021. <https://www.bloomberg.com/news/articles/2021-07-29/record-money-is-flowing-into-climate-tech-what-next>.

Myers, Steven Lee. "The Moon, Mars and Beyond: China's Ambitious Plans in Space." The New York Times, October 15, 2021, sec. World. <https://www.nytimes.com/article/china-mars-space.html>.

"NASA Astronauts Could Live In Future Homes Made of Mushrooms on Mars and the Moon." Accessed January 11, 2022. <https://www.thedailybeast.com/nasa-astronauts-could-live-in-future-homes-made-of-mushrooms-on-mars-and-the-moon>.

Engadget. "NASA Backs Blue Origin's Orbital Reef Space Station." Accessed January 11, 2022. <https://www.engadget.com/nasa-backs-blue-origins-orbital-reef-space-station-220247282>.

html.

MIT Technology Review. "NASA Inches Closer to Printing Artificial Organs in Space." Accessed January 11, 2022. <https://www.technologyreview.com/2021/06/18/1026556/nasa-bio-printing-artificial-organs-space/>.

Climate Change: Vital Signs of the Planet. "NASA-Led Study Reveals the Causes of Sea Level Rise Since 1900." Accessed January 11, 2022. <https://climate.nasa.gov/news/3012/nasa-led-study-reveals-the-causes-of-sea-level-rise-since-1900>

Neuman, Scott. "Scientists Say They Could Bring Back Woolly Mammoths. But Maybe They Shouldn't." NPR, September 15, 2021, sec. Science. <https://www.npr.org/2021/09/14/1036884561/dna-resurrection-jurassic-park-woolly-mammoth>.

"New PSU Graduate Program Tackles the Future of Disasters | KOIN.Com." Accessed January 11, 2022. <https://www.koin.com/local/multnomah-county/new-psu-graduate-program-tackles->

the-future-of-disasters/

Mongabay Environmental News. "New Study Warns That Sea Levels Will Rise Faster than Expected," February 2, 2021. <https://news.mongabay.com/2021/02/new-study-warns-that-sea-levels-will-rise-faster-than-expected/>.

Nogrady, Bianca. "China Launches World's Largest Carbon Market: But Is It Ambitious Enough?" Nature 595, no. 7869 (July 20, 2021): 637-637. <https://doi.org/10.1038/d41586-021-01989-7>.

October 28th 2021, Matt Simon | News | "Are Microplastics Cooling and Heating the Earth's Climate?" Canada's National Observer, October 28, 2021. <https://www.nationalobserver.com/2021/10/28/news/are-microplastics-cooling-and-heating-earths-climate>.

O'Kane, Sean. "Biden's \$7.5 Billion EV Charging Plan Will Require a Lot of Patience." The Verge, November 16, 2021. <https://www.theverge.com/2021/11/16/22765438/biden-in->

frastructure-bill-electric-vehicle-ev-charging-level-2.

"Over 10 Million Displaced by Climate Disasters in Six Months: Report." Reuters, March 17, 2021, sec. Environment. <https://www.reuters.com/article/us-climate-change-displacement-idUSKB-N2B90Z8>.

Peng, Yiming, Peipei Wu, Amina T. Schartup, and Yanxu Zhang. "Plastic Waste Release Caused by COVID-19 and Its Fate in the Global Ocean." Proceedings of the National Academy of Sciences 118, no. 47 (November 23, 2021). <https://doi.org/10.1073/pnas.2111530118>.

"Our Underwater Future: What Sea Level Rise Will Look like around the Globe." Accessed January 11, 2022. <https://www.cnn.com/2021/10/12/world/3-degrees-sea-level-rise-climate-central/index.html>

Ponciano, Jonathan. "Everything In The \$1.2 Trillion Infrastructure Bill: New Roads, Electric School Buses And More." Forbes. Accessed January 11,

Selected Sources

2022. <https://www.forbes.com/sites/jonathanponciano/2021/11/15/everything-in-the-12-trillion-infrastructure-bill-biden-just-signed-new-roads-electric-school-buses-and-more/>.

"The Future of Renewable Fuels in Microgrids: Ameresco." Microgrid Knowledge (blog), December 7, 2021. <https://microgridknowledge.com/the-future-of-renewable-fuels-in-microgrids-ameresco/>.

Elizabeth Howell. "Astronomers Propose 'SatHub' to Address Growing Threat of Satellite Megaconstellations." Space.com, July 28, 2021. <https://www.space.com/sathub-idea-threat-satellite-megaconstellations-astonomy>.

"Can We Reflect Sunlight to Fight Climate Change? Scientists Eye Aerosol Shield for Earth." Space.com, April 19, 2021. <https://www.space.com/global-warming-aerosol-reflector-block-sunlight>.

"NASA Awards \$415 Million for Private Space Stations amid ISS Transition Questions." Space.com, December

3, 2021. <https://www.space.com/nasa-private-space-station-design-contracts>.

"NASA's James Webb Space Telescope on Track for Dec. 22 Launch." Space.com, November 30, 2021. <https://www.space.com/nasa-webb-space-telescope-december-22-launch>.

Mike Wall. "Amazon to Launch 1st Prototype Internet Satellites for Kuiper Constellation in 2022." Space.com, November 1, 2021. <https://www.space.com/amazon-kuiper-prototype-internet-satellites-launch-2022>.

"Russia and China Just Agreed to Build a Research Station on the Moon Together." Space.com, March 10, 2021. <https://www.space.com/russia-china-moon-research-station-agreement>.

Paul Sutter. "Megaconstellations Could Destroy Astronomy and There's No Easy Fix." Space.com, October 6, 2021. <https://www.space.com/megaconstellations-could-destroy-astronomy-no-easy-fix>.

Scott Duffield. "Record-High Astronaut Applications Overwhelm European Space Agency." Space.com, August 31, 2021. <https://www.space.com/european-astronaut-applications-esa-2021-delays>.

Rakib, Md Refat Jahan, Sultan Al Nahian, María B. Alfonso, Mayeen Uddin Khandaker, Christian Ebere Enyoh, Fauziah Shahul Hamid, Abdullah Alsubaie, et al. "Microplastics Pollution in Salt Pans from the Maheshkhali Channel, Bangladesh." Scientific Reports 11, no. 1 (November 30, 2021): 23187. <https://doi.org/10.1038/s41598-021-02457-y>.

ScienceDaily. "Recycled Concrete and CO2 from the Air Are Made into a New Building Material." Accessed January 11, 2022. <https://www.sciencedaily.com/releases/2021/10/211007122058.htm>.

"Red Alert: It Rained in Greenland's Ice Sheet for the First Time in Recorded History." Accessed January 11, 2022. <https://futurism.com/the-byte/rained-greenlands-ice-sheet-first-time-recorded-history>

Rehm, Jeremy, and Meghan Bartels published. "UAE Hope Mars Orbiter: The Arab World's First Interplanetary Mission." Space.com, May 3, 2021. <https://www.space.com/hope-mars-mission-uae>.

IEA. "Renewables 2021 – Analysis." Accessed January 11, 2022. <https://www.iea.org/reports/renewables-2021>.

"Report: China Emissions Exceed All Developed Nations Combined." BBC News, May 7, 2021, sec. Asia. <https://www.bbc.com/news/world-asia-57018837>.

"Look: UAE's Hope Probe Reveals First 'Full Day', Seasonal Pictures of Mars." Khaleej Times. Accessed January 11, 2022. <https://www.khaleejtimes.com/uae/look-uaes-hope-probe-reveals-first-full-day-seasonal-pictures-of-mars>.

Revell, Laura E., Peter Kuma, Eric C. Le Ru, Walter R. C. Somerville, and Sally Gaw. "Direct Radiative Effects of Airborne Microplastics." Nature 598, no. 7881 (October 2021): 462–67. <https://doi.org/10.1038/s41586-021-03864-x>.

doi.org/10.1038/s41586-021-03864-x.

Ryan, Jackson. "Machines That Suck CO2 out of the Air Promise to Reverse Emissions. Will They Work?" CNET. Accessed January 11, 2022. <https://www.cnet.com/news/machines-that-suck-co2-out-of-the-air-promise-to-reverse-emissions-will-they-work/>.

TechCrunch. "Salesforce Reaches Net Zero Energy Usage, Announces Updates to Sustainability Cloud." Accessed January 11, 2022. <https://social.techcrunch.com/2021/09/21/salesforce-reaches-net-zero-energy-usage-announces-updates-to-sustainability-cloud/>.

Sanchez, Juan A., Vishnu Reddy, William F. Bottke, Adam Battle, Benjamin Sharkey, Theodore Kareta, Neil Pearson, and David C. Cantillo. "Physical Characterization of Metal-Rich Near-Earth Asteroids 6178 (1986 DA) and 2016 ED85." The Planetary Science Journal 2, no. 5 (October 1, 2021): 205. <https://doi.org/10.3847/PSJ/ac235f>.

"Satellite Database | Union of Con-

Selected Sources

cerned Scientists." Accessed January 11, 2022. <https://www.ucusa.org/resources/satellite-database>.

"Secretary Haaland Outlines Ambitious Offshore Wind Leasing Strategy," October 13, 2021. <https://www.doi.gov/pressreleases/secretary-haaland-outlines-ambitious-offshore-wind-leasing-strategy>.

Service, Purdue News. "Electric Vehicles Could Fully Recharge in under 5 Minutes with New Charging Station Cable Design." Accessed January 11, 2022. <https://www.purdue.edu/newsroom/releases/2021/Q4/electric-vehicles-could-fully-recharge-in-under-5-minutes-with-new-charging-station-cable-design.html>.

Sheetz, Michael. "SpaceX Launches a 'rideshare' Mission Carrying 143 Spacecraft, a Record for a Single Launch." CNBC, January 24, 2021. <https://www.cnbc.com/2021/01/24/spacex-launches-rideshare-mission-with-143-spacecraft.html>.

Shepherd, Tory. "'Gas Station in Space':

New Plan to Make Rocket Fuel from Junk in Earth's Orbit." The Guardian, November 19, 2021, sec. Science. <https://www.theguardian.com/science/2021/nov/20/gas-station-in-space-new-plan-to-make-rocket-fuel-from-junk-in-earths-orbit>.

pv magazine International. "South Korea's Largest Floating PV Plant Now Online." Accessed January 11, 2022. <https://www.pv-magazine.com/2021/11/25/south-koreas-largest-floating-pv-plant-now-online-2/>.

Southwell, Hazel. "Ford, Purdue Cooling Patent Could Charge EVs As Fast As Gas Station Fill-Ups." The Drive. Accessed January 11, 2022. <https://www.thedrive.com/tech/43155/ford-purdue-cooling-patent-could-charge-evs-as-fast-as-gas-station-fill-ups>.

TechCrunch. "Spaceflight Aims to Send Customer Payloads to Two Separate Orbits for the First Time." Accessed January 11, 2022. <https://social.techcrunch.com/2021/11/09/spaceflight-aims-to-send-customer-payloads-to-two-separate-orbits-for-the-first-time/>.

Stevens, Pippa. "ESG Index Funds Hit \$250 Billion as Pandemic Accelerates Impact Investing Boom." CNBC, September 2, 2020. <https://www.cnbc.com/2020/09/02/esg-index-funds-hit-250-billion-as-us-investor-role-in-boom-grows.html>.

Storer, Rhi. "Up to 410 Million People at Risk from Sea Level Rises - Study." The Guardian, June 29, 2021, sec. Environment. <https://www.theguardian.com/environment/2021/jun/29/risk-from-sea-level-rises-unless-emissions-reduced>

"Teva Pharmaceuticals Plans \$5 Billion Sustainability-Linked Bond Tied to Climate and Access to Medicine Targets - MarketWatch." Accessed January 11, 2022. <https://www.marketwatch.com/story/teva-pharmaceuticals-plans-5-billion-sustainability-linked-bond-tied-to-climate-and-access-to-medicine-targets-2021-11-03>

MIT Technology Review. "The 11 Biggest Space Missions of 2021 (and Their Chances of Success)." Accessed January 11, 2022. <https://www.technologyre->

<view.com/2021/01/04/1015519/the-11-biggest-space-missions-of-2021/>.

IEA. "The Future of Hydrogen - Analysis." Accessed January 11, 2022. <https://www.iea.org/reports/the-future-of-hydrogen>.

Futurism. "The Mighty James Webb Space Telescope Is All Fueled Up for Launch." Accessed January 11, 2022. <https://futurism.com/the-byte/james-webb-telescope-fuel>.

"The Mycelium Era: How Mushrooms Could Stop Climate Change," August 20, 2021. <https://interestingengineering.com/mycelium-savior-how-mushrooms-are-fighting-climate-change>.

The Ocean Cleanup. "The Ocean Cleanup." Accessed January 11, 2022. <https://theoceancleanup.com/>.

Marketplace. "The U.K. Aspires to Become the 'Qatar of Hydrogen,'" November 30, 2021. <https://www.marketplace.org/2021/11/30/the-u-k-aspires-to-become-the-qatar-of-hydrogen/>.

"The Unsinkable Libertarian Dream of the Floating City - Bloomberg." Accessed January 11, 2022. <https://www.bloomberg.com/news/articles/2018-04-27/the-unsinkable-libertarian-dream-of-the-floating-city>

"The Year Space Got Sexy All Over Again - The New York Times." Accessed January 11, 2022. <https://www.nytimes.com/2021/12/10/style/space-billionaires.html>

World Economic Forum. "These Are the Top 10 Emerging Technologies of 2021." Accessed January 11, 2022. <https://www.weforum.org/agenda/2021/11/these-are-the-top-10-emerging-technologies-of-2021/>.

"This Solar Geoengineering Idea Has a Goldilocks Problem - Welcome to NOAA Research." Accessed January 11, 2022. <https://research.noaa.gov/article/ArtMID/587/ArticleID/2798/This-solar-geoengineering-idea-has-a-Goldilocks-problem>

Tollefson, Jeff. "Can Artificially Altered Clouds Save the Great Barrier Reef?"

Selected Sources

Nature 596, no. 7873 (August 25, 2021): 476–78. <https://doi.org/10.1038/d41586-021-02290-3>.

“Top1 Unveils Blockchain-as-a-Service to Make ESG Easier Than Ever,” April 20, 2021. <https://www.businesswire.com/news/home/20210420005333/en/Top1-Unveils-Blockchain-as-a-Service-to-Make-ESG-Easier-Than-Ever>.

“Total, Air Liquide Invest in \$1.7 Billion Green Hydrogen Fund.” Bloomberg. Com, October 1, 2021. <https://www.bloomberg.com/news/articles/2021-10-01/total-air-liquide-invest-in-1-7-billion-green-hydrogen-fund>.

“Total (TTE), Air Liquide Invest in \$1.7 Billion Green Hydrogen Fund - Bloomberg.” Accessed January 11, 2022. <https://www.bloomberg.com/news/articles/2021-10-01/total-air-liquide-invest-in-1-7-billion-green-hydrogen-fund>

NBC News. “UAE to Launch Probe Targeting Asteroid between Mars, Jupiter.” Accessed January 11, 2022. <https://www.nbcnews.com/science/space/>

uae-launch-probe-targeting-asteroid-mars-jupiter-rcna2606.

“US Firefighters Turn to AI to Battle the Blazes.” Christian Science Monitor, July 23, 2021. <https://www.csmonitor.com/Environment/2021/0723/US-firefighters-turn-to-AI-to-battle-the-blazes>

MIT News | Massachusetts Institute of Technology. “Using Aluminum and Water to Make Clean Hydrogen Fuel — When and Where It’s Needed.” Accessed January 11, 2022. <https://news.mit.edu/2021/using-aluminum-and-water-to-make-clean-hydrogen-fuel-0812>.

Vaidyanathan, Gayathri. “The World’s Species Are Playing Musical Chairs: How Will It End?” Nature 596, no. 7870 (August 4, 2021): 22–25. <https://doi.org/10.1038/d41586-021-02088-3>.

True Nature Foundation. “What Is Rewilding?” Accessed January 11, 2022. <https://truenaturefoundation.org/what-is-rewilding/>.

Science ABC. “What Is Rewilding And Why Is It Important?,” October 28, 2020.

<https://www.scienceabc.com/nature/animals/what-is-rewilding-and-why-is-it-important.html>.

Boston Review. “Whose Anthropocene?” Accessed January 10, 2022. <https://bostonreview.net/articles/whose-anthropocene/>.

Grist. “Why a Landmark Experiment into Dimming the Sun Got Canceled,” April 8, 2021. <https://grist.org/science/who-gets-to-decide-if-we-study-solar-geoengineering-after-the-scopex-project-canceled/>.

“Why China’s Climate Policy Matters to Us All.” BBC News, October 29, 2021, sec. China. <https://www.bbc.com/news/world-asia-china-57483492>.

Williams, Matt, and Universe Today. “There’s Now a Gas Station in Space.” Accessed January 11, 2022. <https://phys.org/news/2021-09-gas-station-space.html>.

Wolchover, Natalie. “The Webb Space Telescope Will Rewrite Cosmic History. If It Works.” Quanta Magazine,

December 3, 2021. <https://www.quantamagazine.org/why-nasas-james-webb-space-telescope-matters-so-much-20211203/>.

Wright, Katherine. “Ignition First in a Fusion Reaction.” Physics 14 (November 30, 2021): 168.

Zhang, Duo, Lucca Henrion, Victor C. Li, and Volker Sick. “Bendable Concrete and Other CO2-Infused Cement Mixes Could Dramatically Cut Global Emissions.” The Conversation. Accessed January 11, 2022. <http://theconversation.com/bendable-concrete-and-other-co2-infused-cement-mixes-could-dramatically-cut-global-emissions-152544>.

Zimmer, Carl. “A New Company With a Wild Mission: Bring Back the Woolly Mammoth.” The New York Times, September 13, 2021, sec. Science. <https://www.nytimes.com/2021/09/13/science/colossal-woolly-mammoth-DNA.html>.



