14th Annual Edition

# Tech Trends Report

Strategic trends that will influence business, government, education, media and society in the coming year.

Future Today Institute

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Volume 0 of 12

14th Annual Edition

# 2021 Tech Trends Report

Strategic trends that will influence business, government, education, media and society in the coming year.

- Overview
- Methodology
- Frameworks

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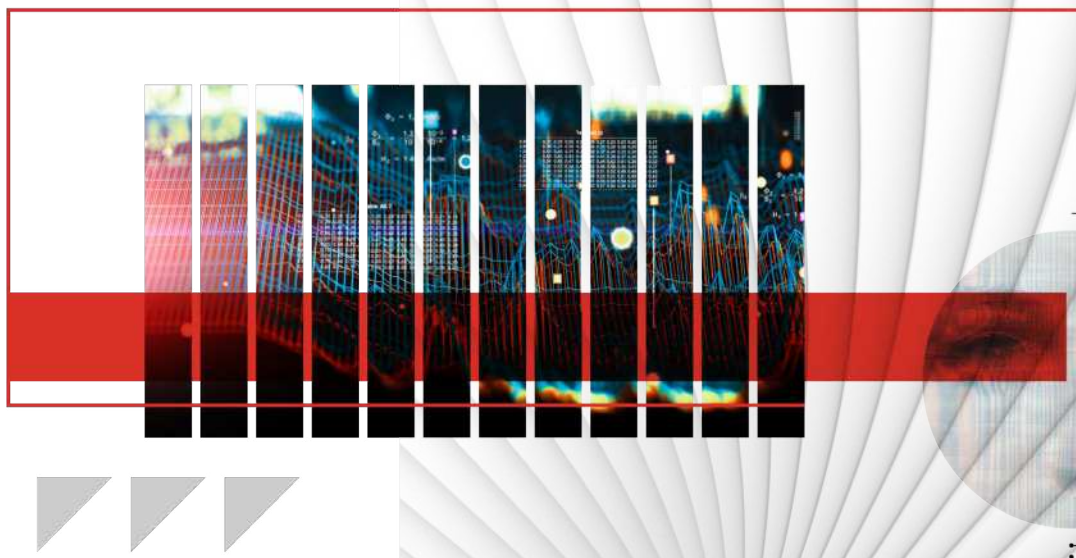

# Overview

The 1920s began in chaos. Cataclysmic disruption resulting from the first world war and the Spanish flu shuttered businesses and provoked xenophobia. Technological marvels like the radio, refrigerator, vacuum cleaner, moving assembly line and electronic power transmission generated new growth, even as the wealth gap widened. More than two-thirds of Americans survived on wages too low to sustain everyday living. The pace of scientific innovation—the discovery of insulin, the first modern antibiotics, and insights into theoretical physics and the structure of atoms—forced people to reconsider their cherished beliefs.

The sheer scale of change, and the great uncertainty that came with it, produced two factions: those who wanted to reverse time and return the world to normal, and those who embraced the chaos, faced forward, and got busy building the future.

It's difficult not to see striking parallels to our modern world. A tumultuous U.S. election, extreme weather events and Covid-19 continue to test our resolve and our resilience. Exponential technologies—artificial intelligence, synthetic biology, exascale computing, autonomous robots, and off-planet missions to space—are challenging our assumptions about human potential. Under lockdown, we've learned how to work from our kitchen tables, lead from our spare rooms, and support each other from afar. But this disruption has only just begun.

With the benefit of both hindsight and strategic foresight, we can choose a path of reinvention. Our 2021 Tech Trends Report is designed to help you confront deep uncertainty, adapt and thrive. For this year's edition, the magnitude of new signals required us to create 12 separate volumes, and each report focuses on a cluster of related trends. In total, we've analyzed nearly 500 technology and science trends across multiple industry sectors. In each volume, we discuss the disruptive forces, opportunities and strategies that will drive 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. From chaos, a new world will come.

**Amy Webb**

Founder
The Future Today Institute



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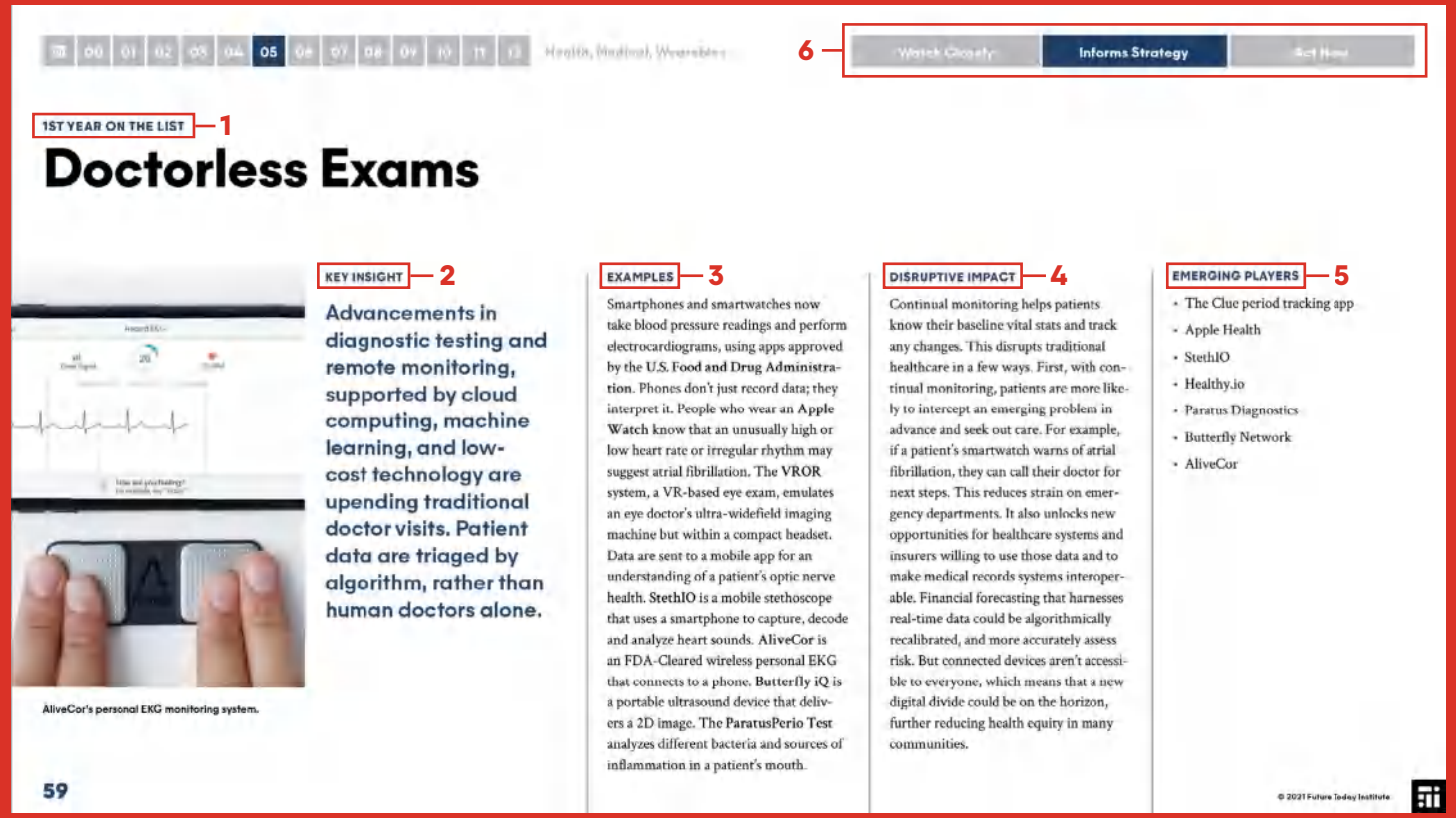
# Macro Forces and Emerging Trends

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 14th 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 500 trends into 12 clear categories.**

Within those categories are specific use cases and recommendations for key roles in many organizations: strategy, innovation, R&D, and risk.



6 Watch Closely | Informs Strategy | Act Now

1ST YEAR ON THE LIST — 1

## Doctorless Exams

KEY INSIGHT — 2

Advancements in diagnostic testing and remote monitoring, supported by cloud computing, machine learning, and low-cost technology are upending traditional doctor visits. Patient data are triaged by algorithm, rather than human doctors alone.

AliveCor's personal EKG monitoring system.

EXAMPLES — 3

Smartphones and smartwatches now take blood pressure readings and perform electrocardiograms, using apps approved by the U.S. Food and Drug Administration. Phones don't just record data; they interpret it. People who wear an Apple Watch know that an unusually high or low heart rate or irregular rhythm may suggest atrial fibrillation. The VROR system, a VR-based eye exam, emulates an eye doctor's ultra-widefield imaging machine but within a compact headset. Data are sent to a mobile app for an understanding of a patient's optic nerve health. StethIO is a mobile stethoscope that uses a smartphone to capture, decode and analyze heart sounds. AliveCor is an FDA-Cleared wireless personal EKG that connects to a phone. Butterfly iQ is a portable ultrasound device that delivers a 2D image. The ParatusPerio Test analyzes different bacteria and sources of inflammation in a patient's mouth.

DISRUPTIVE IMPACT — 4

Continual monitoring helps patients know their baseline vital stats and track any changes. This disrupts traditional healthcare in a few ways. First, with continual monitoring, patients are more likely to intercept an emerging problem in advance and seek out care. For example, if a patient's smartwatch warns of atrial fibrillation, they can call their doctor for next steps. This reduces strain on emergency departments. It also unlocks new opportunities for healthcare systems and insurers willing to use those data and to make medical records systems interoperable. Financial forecasting that harnesses real-time data could be algorithmically recalibrated, and more accurately assess risk. But connected devices aren't accessible to everyone, which means that a new digital divide could be on the horizon, further reducing health equity in many communities.

EMERGING PLAYERS — 5

- The Clue period tracking app
- Apple Health
- StethIO
- Healthy.io
- Paratus Diagnostics
- Butterfly Network
- AliveCor

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## 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 emerging in this space.

### 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 it to inform your vision, planning, and research.

**Informs Strategy**

Strong evidence and data. Longer-term uncertainties remain. Use it to inform your strategic planning.

**Act Now**

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



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# Macro Forces and Emerging Trends

## 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.

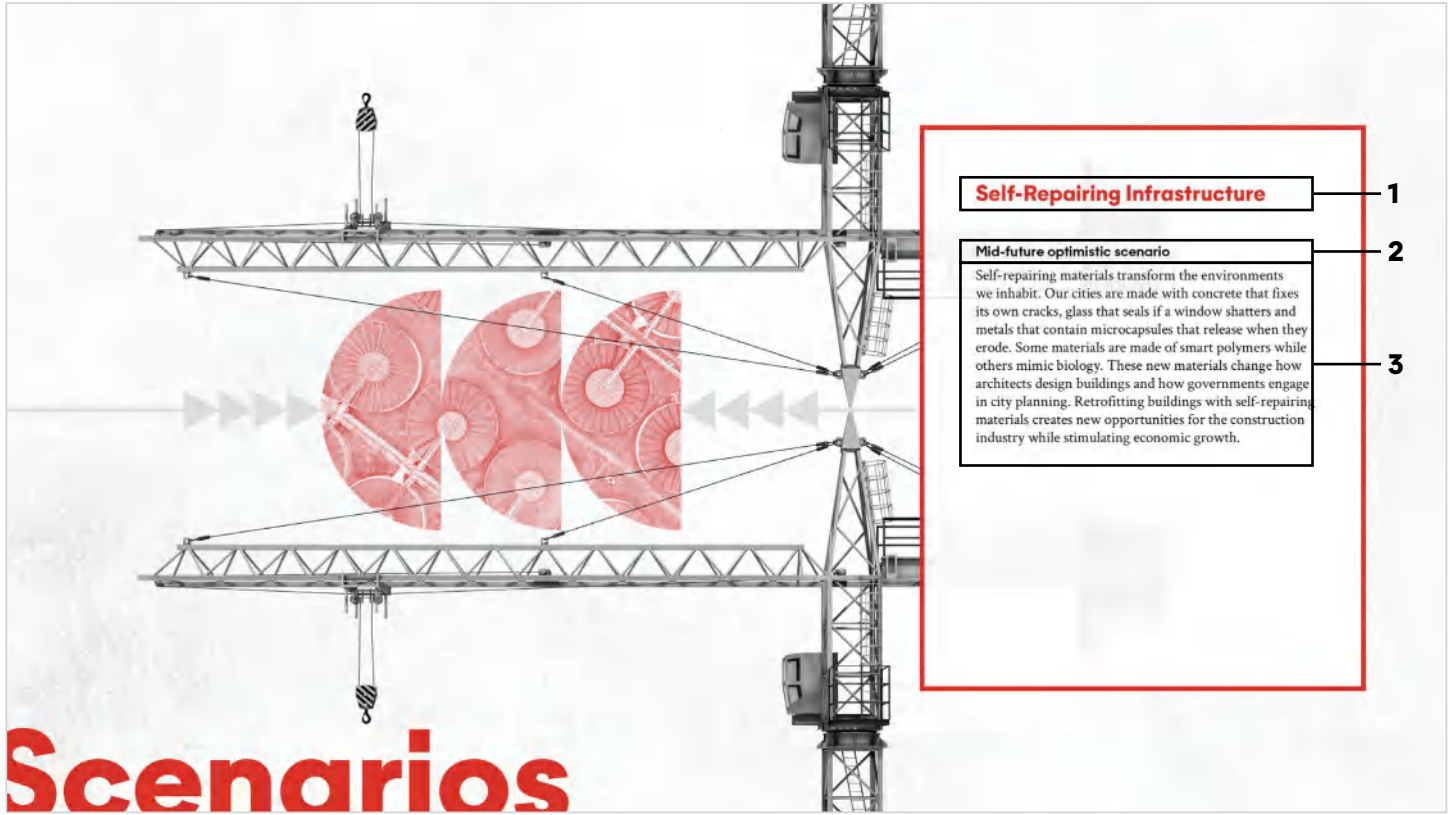
### 2. Temporal and Emotive Tags

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.



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# Methodology

## 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 1 and 5.

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.



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# The 11 Sources

## Macro Forces

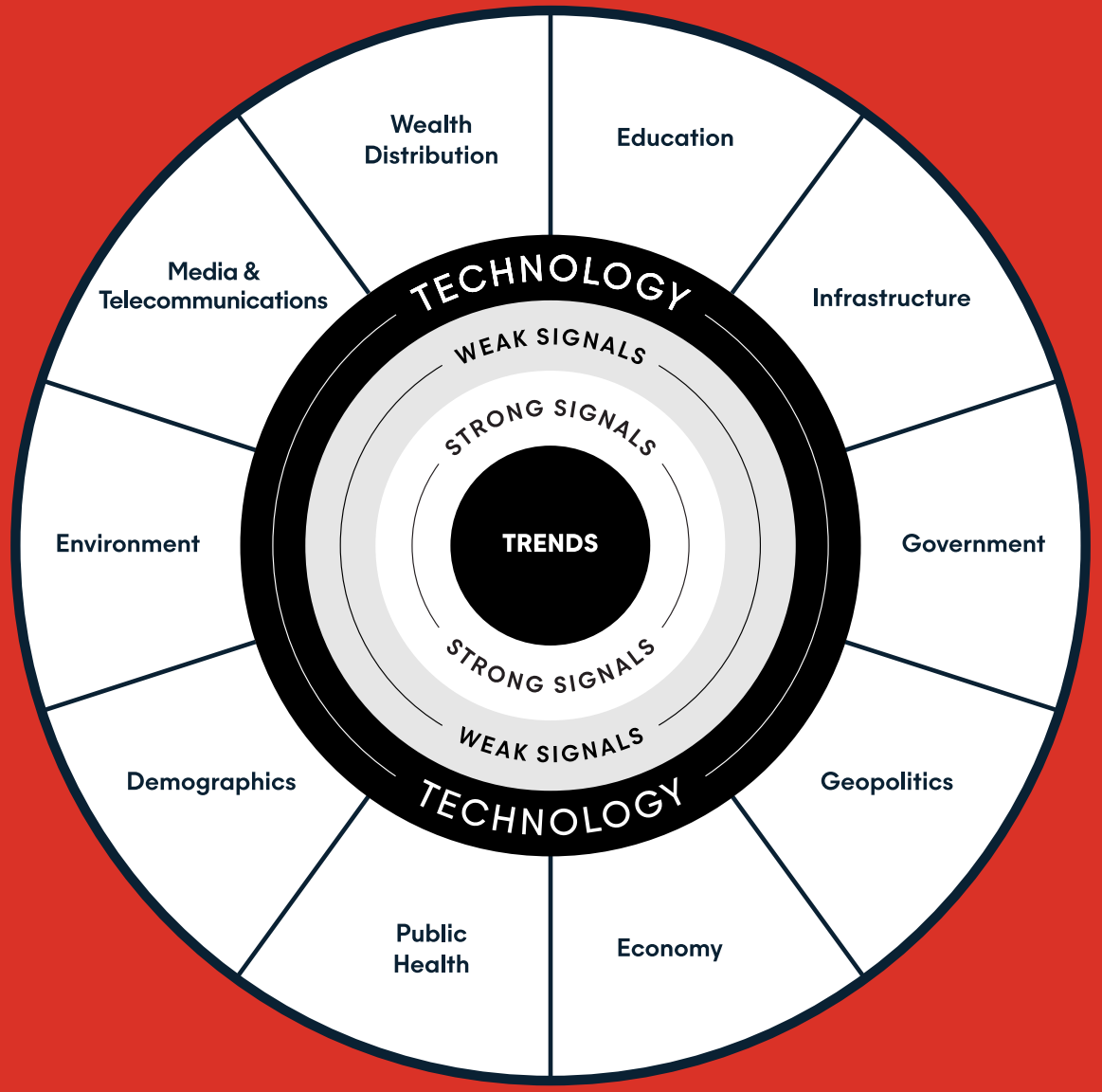
Shape our world

## Signals

Indicate emerging change

## Trends

Describe our futures



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# The 11 Sources

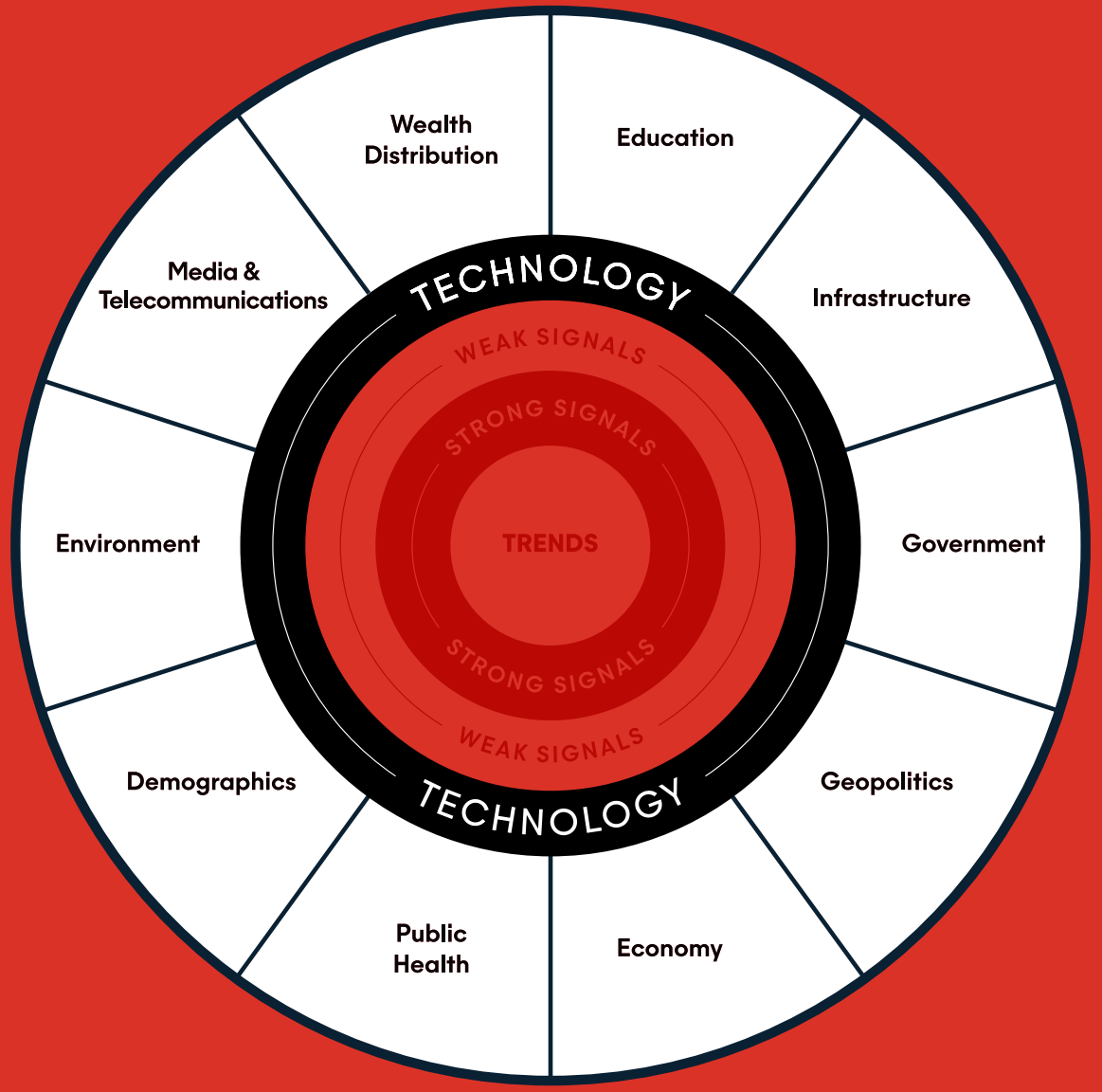
## Macro Forces

### Shape our world

These 11 Macro Forces represent external uncertainties 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 Forces impact the world we live in.

FTI Senior Foresight Associate Marc Palatucci refers to this framework as our "Wheel of Disruption." 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.

We also consider each of the macro sources to ensure that our framing includes areas beyond one industry and its direct adjacencies. The result is a diverse set of clear drivers we use to guide our research and analysis.



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# The 11 Sources

## Macro Forces

### Shape our world

**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.

**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.



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# The 11 Sources

## 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

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# The 11 Sources

## Trends

### Describe our futures

Trends emerge from the intersection of macro forces and signals. They are new manifestations representing the collisions of new developments, and they form steadily over many years. Importantly, they do not necessarily follow a linear path from the fringe to the mainstream.

**The Four Laws of Tech Trends**

1. Trends are driven by primary forces of change and our basic human needs.
2. Trends are timely, but they persist in the wake of new developments.
3. Trends are the convergence of weak and strong signals over time.
4. Trends evolve as they emerge.

The Four Laws of Tech Trends were first introduced in *The Signals Are Talking: Why Today's Fringe Is Tomorrow's Mainstream* by Amy Webb.

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# 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 Four Laws of Tech Trends.

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 Four Laws 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.



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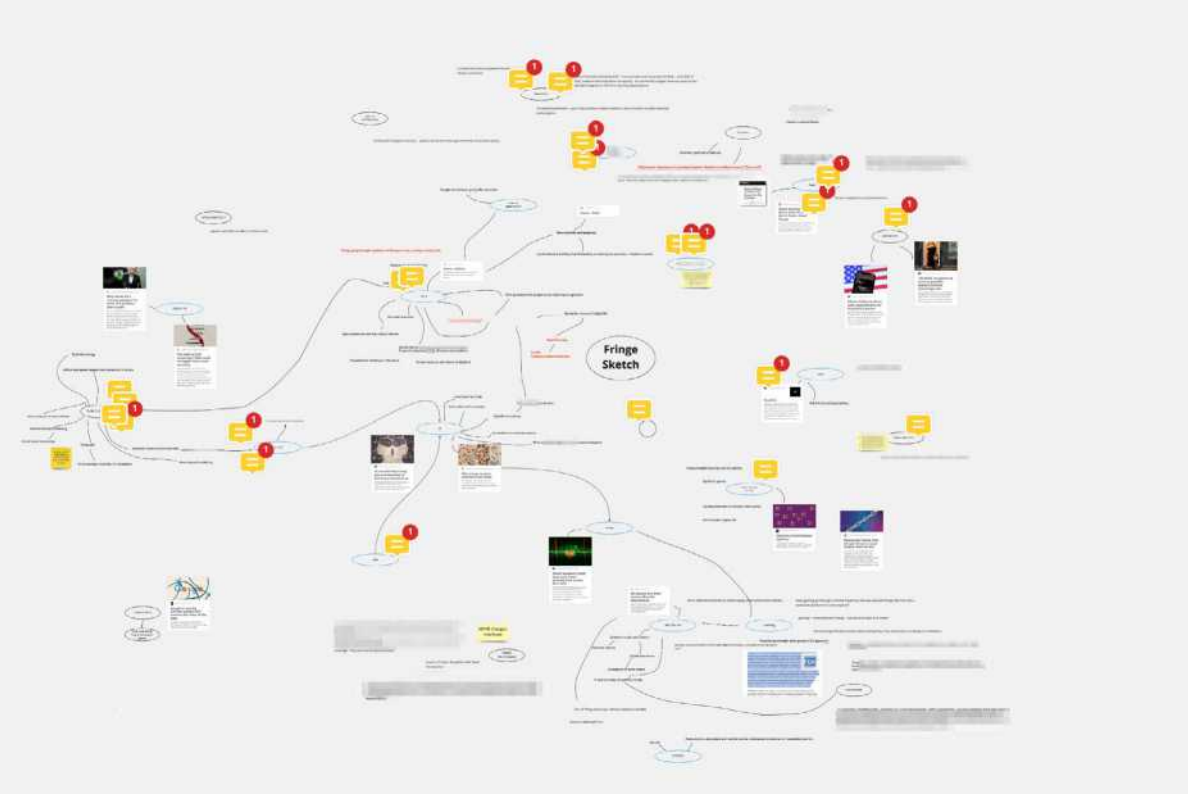
# Fringe Sketching

The Fringe Sketch is FTI's first step in looking for emerging signals and trends. It is a network map connecting signals to macro forces. We build the sketch using a digital whiteboard, and add data sources, images, videos, and other relevant bits of information as we go.

We begin by adding a wide array of relevant idea "nodes" to the sketch—these can include concisely described current events, emerging tech trends, societal phenomena, even additional questions—and drawing lines between each node and those to which it is most closely related. This process takes the form of an active brainstorm, with thoughts flowing freely and most, if not all of them, making it into the sketch. We keep at it until we have an explosive amount of ideas on the board, each forming a node and spawning its own sub-nodes in a many-layered web of information.

The result is a map of direct and orthogonal relationships between diverse technological and cultural phenomena, all with the central topic as their nucleus. This collection of structured data can then be analyzed to reveal unexpected interactions and surface overarching trends that are likely to play a role in the future.



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# 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 |



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# Escalation Triggers

Signals and trends aren't useful within an organization unless strategic action of some kind is taken. Teams sometimes have a difficult time aligning on which trends to share with executives—and when.

We customize this Escalation Triggers matrix for our FTI clients to help them determine when they should take action, when a strategic decision is needed, and when to continue monitoring a signal or trend (or constellation of signals and trends). With each new signal discovered, they use this matrix to determine the category. If the answer in a category is predominantly yes, they know when to escalate the signal to other departments, executive teams, or boards of directors.

## Action Criteria

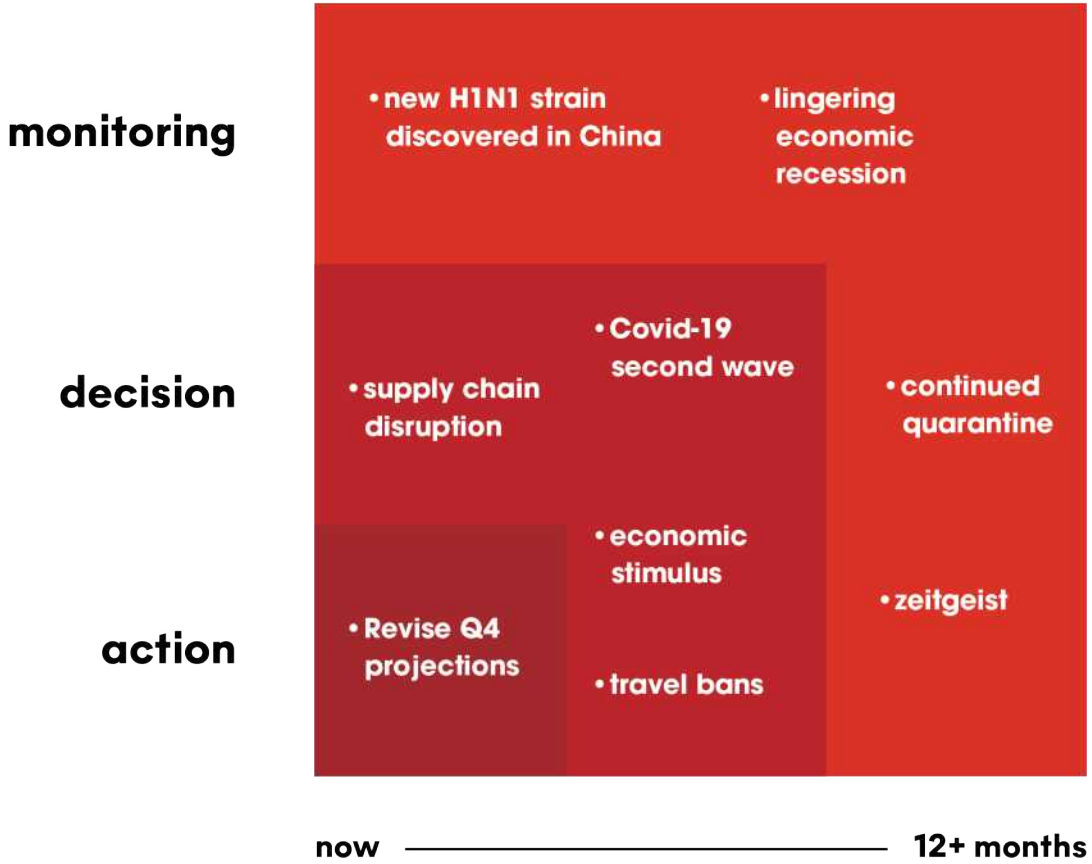
- Inflection point is imminent
- Immediate opportunity for competitor
- Impacts our partners
- Great internal momentum/support in our organization

## Decision Criteria

- High importance and/ or high impact
- Could cause disruption to our model
- Financial, operational or market risk
- Meaningful impact on brand positioning
- Tied to an existing strategic initiative
- Pending regulation
- Strong interest from within our organization

## Monitoring Criteria

- Potential for financial, operational or market disruption
- Some importance and/or impact, but more time is needed
- Interest from within our organization



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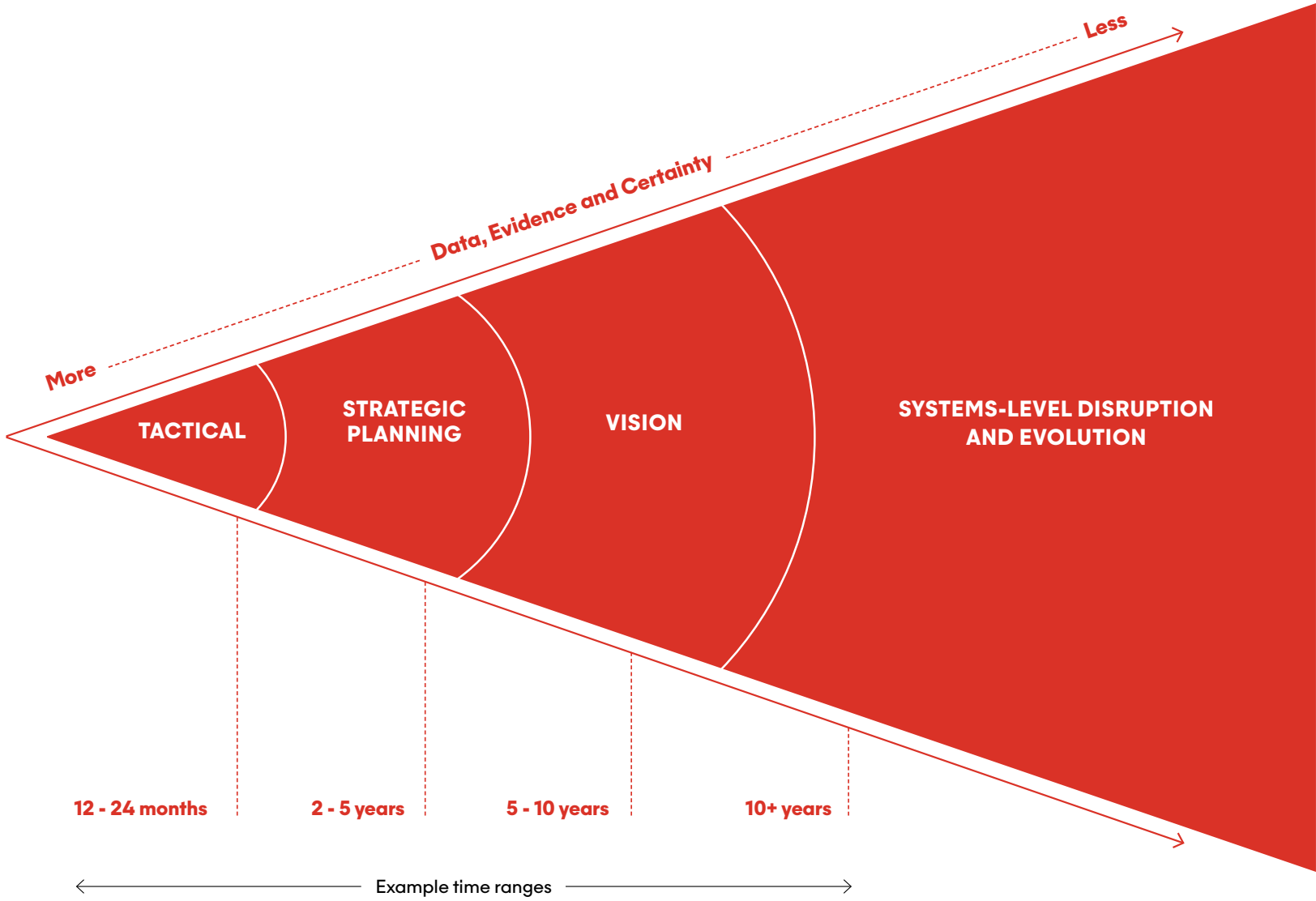
# Time Cone

The Future Today Institute's 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. Timelines are useful for tracking the progress of a project toward a finite goal, but for an organization faced with a broad range of potential futures, you need to factor in uncertainty. The time span of the cone (Tactics, Strategic Planning, Vision, and Systems-Level Evolution) are modulated to suit different foresight projects, and foreseeable waypoints can be plotted directly on the framework. We also map trends on the Time Cone to gain deeper insights into how they could impact organizations.



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# 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) tactics, (2) strategic planning, (3) vision, and (4) systems-level evolution.

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 decisions 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 a systems-level evolution, another organization will drag you into its version of the future.

**Think exponentially.**

**Act incrementally.**



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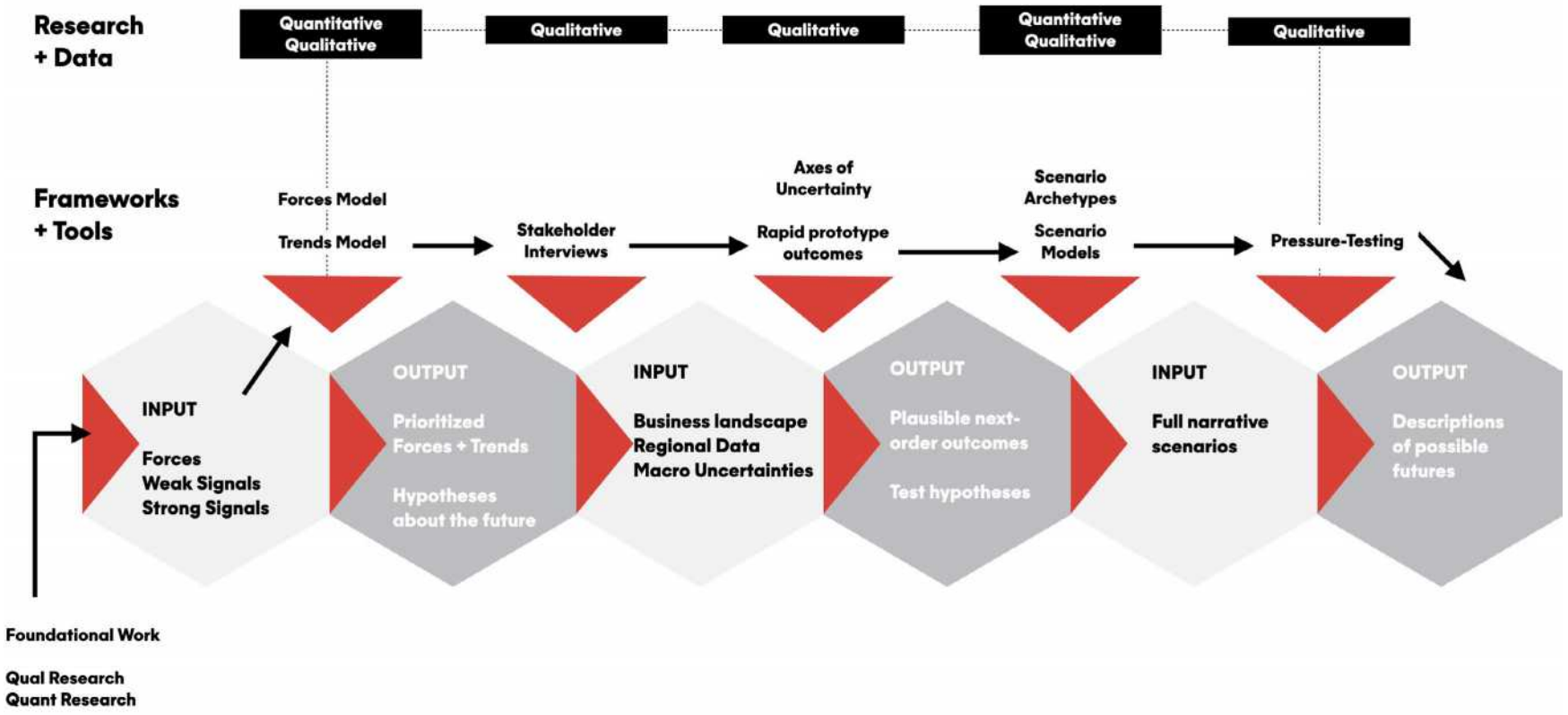
# Scenarios

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

## Our Scenario Modeling Process



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# Axes of Uncertainty

We tend to underpredict or overpredict change. The reason: Imagining plausible outcomes forces us to confront our expectations and cherished beliefs.

We use a 2x2 matrix to rapidly prototype scenarios. They are short but detailed narratives describing plausible outcomes of high-impact, high-uncertainty events.

We begin with a prioritized list of signals and trends. Then we generate an additional list of uncertainties using STEEPLE factors: Social/Demographic, Technological, Economic, Environmental, Political, Legal, and Ethical. We add in additional uncertainties that intrigue us and relate to our current project.

We write uncertainties along opposite axes to explore what scenario might emerge. Quadrants reflect the signals, trends, STEEPLE factors, and other curiosities we're exploring. In each quadrant, we answer "What if these two factors are present?" and continue probing until we have a short but deep story. We finish with a headline describing that future state.

As a last step, we label each quadrant using one of six categories: near-term opportunity, long-term opportunity, near-term risk, long-term risk, neutral, and existential risk to help us prioritize the quadrant for the next phase of our scenarios work.

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# 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.

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# Future States

As we develop scenarios, we first determine the time horizon, the types of data we'll use to support the narrative, and the strategic purpose they will serve.

| | Time Horizon | Characteristics | Strategic Purpose |
|---|---|---|---|
| Probable | Near-future<br>now - 5 years | Ample quantitative data<br>Limited unknown variables<br>Limited volatility | Making near-term tactical decisions |
| Plausible | Mid-future<br>5 - 15 years | Limited data<br>Many unknown variables<br>Follows laws of governing/ society/ physics | Building strategic direction/ vision<br>Looking for investments |
| Possible | Farther-future<br>15+ years | Little or no data<br>May not follow laws of governing/ society/ physics | Long-term planning<br>Systems-level evolution |



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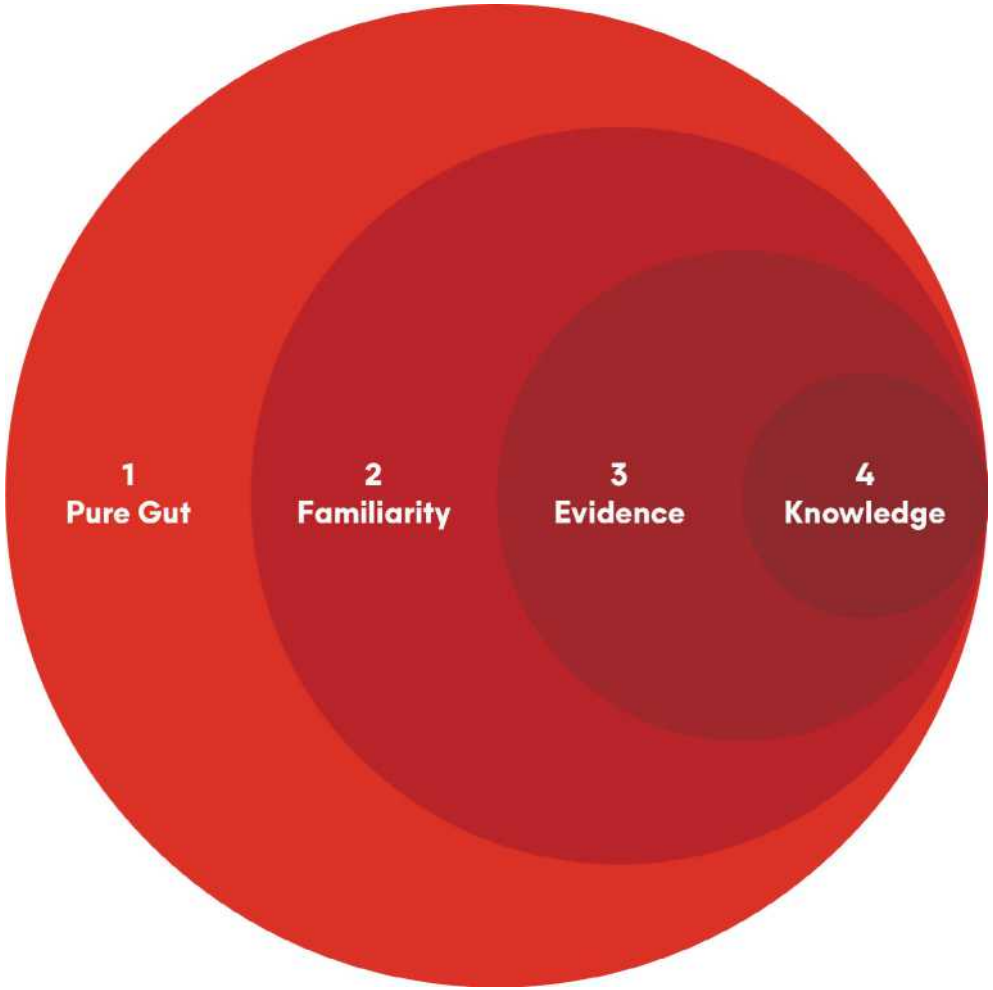
# Assumptions vs. Knowledge

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



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# Scoping and Refining

We ask clients whether they need actions or insights. We also assess their tolerance for risk and uncertainty. This strategic assessment is used to scope our work with clients at the beginning of projects and to refine the questions organizations are seeking to answer.

NEED ACTIONS → NEED INSIGHTS →

CERTAINTY ABOUT TRENDS: LESS ← → MORE

**Tactical Actions**

Find incremental actions that can be taken and measured under current conditions.

**Inform Strategy**

Determine how these trends support or challenge the organization's usual strategic direction. Data, evidence, and models will help the ideas land internally.

**Big Bets**

Architect "big bets" that could help the organization achieve its goals in the future. Reverse-engineer those big bets to the present for incremental actions.

**Explore Ideas**

Explore the recently plausible using an array of adjacent sources of ideas and inspiration. Look for new opportunity spaces to unlock, or emerging threats that haven't yet been considered.

## 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

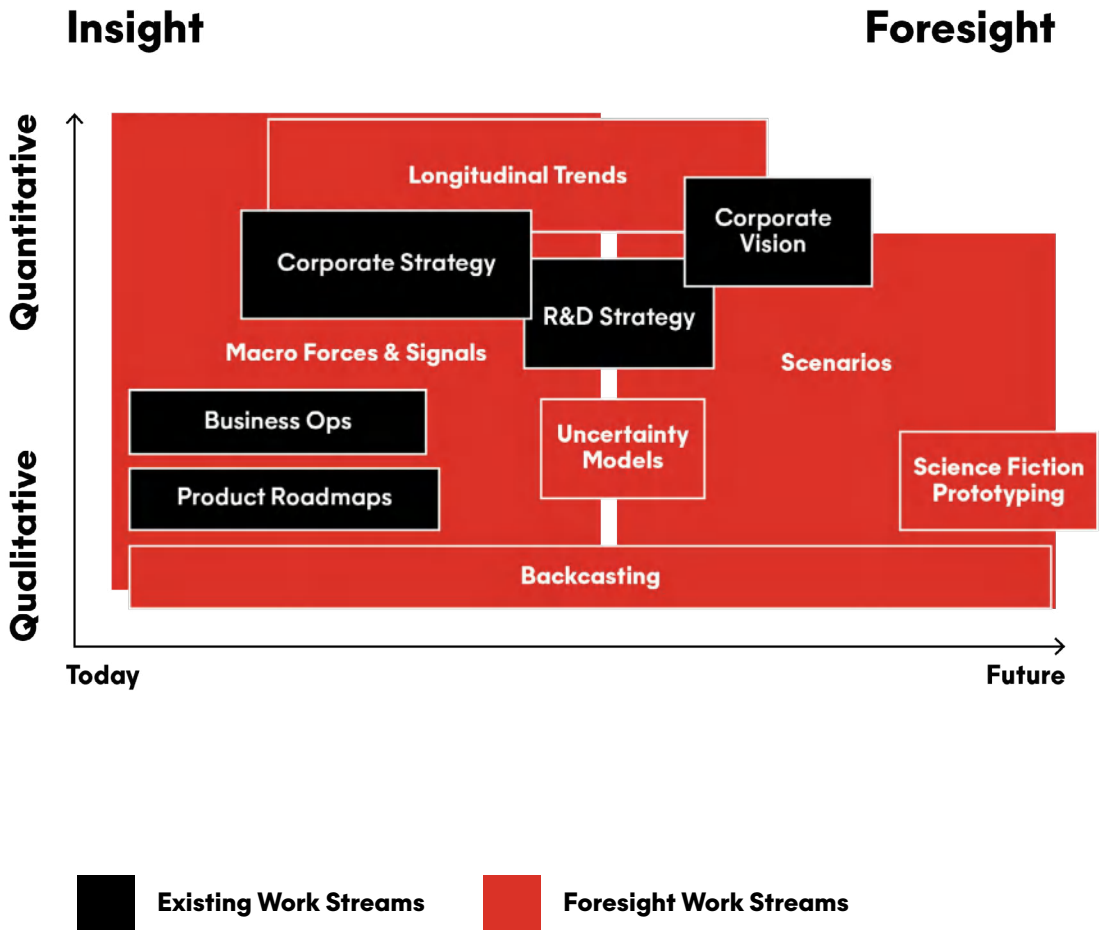
Companies with a dedicated strategic foresight methodology and resources outgrew their competitors 200%.

### 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 Compliments Existing Work Streams



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Editor



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# Why FTI

## We answer your most challenging questions using data, creative inquiry, and strategic foresight.

- What are plausible deep (20+ years), long-range (10+ years), and near-term (2+ years) futures?
- What scenarios describe our futures?
- What's happening outside my industry that I should know?
- What companies, startups, and partners make up our future value network?
- What new products, services, or businesses should we build?
- Which tech trends should we monitor? When should we act?
- How can we build an early warning system to see the next disruptive event?
- How do we reduce uncertainty about our futures?

## We support 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. Advisory services include signal mapping, trend identification, scenario development, risk modeling, visioning, and strategic planning.



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# 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.

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# Appendix

## Value of Foresight: Sources

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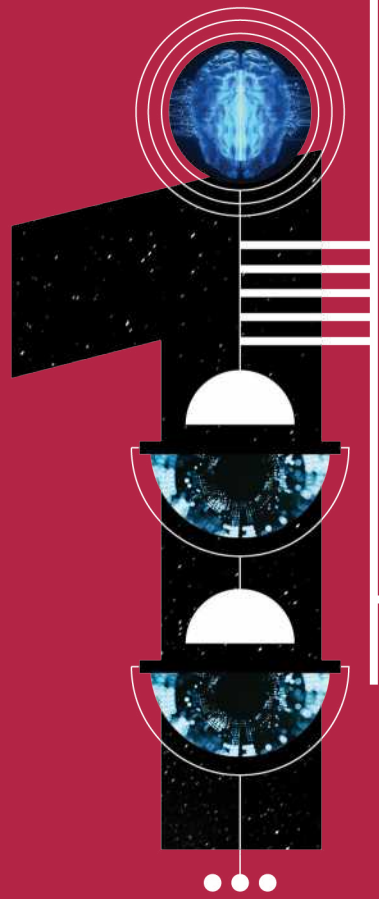
Volume 1 of 12

14th Annual Edition

# 2021 Tech Trends Report

Strategic trends that will influence business, government, education, media and society in the coming year.



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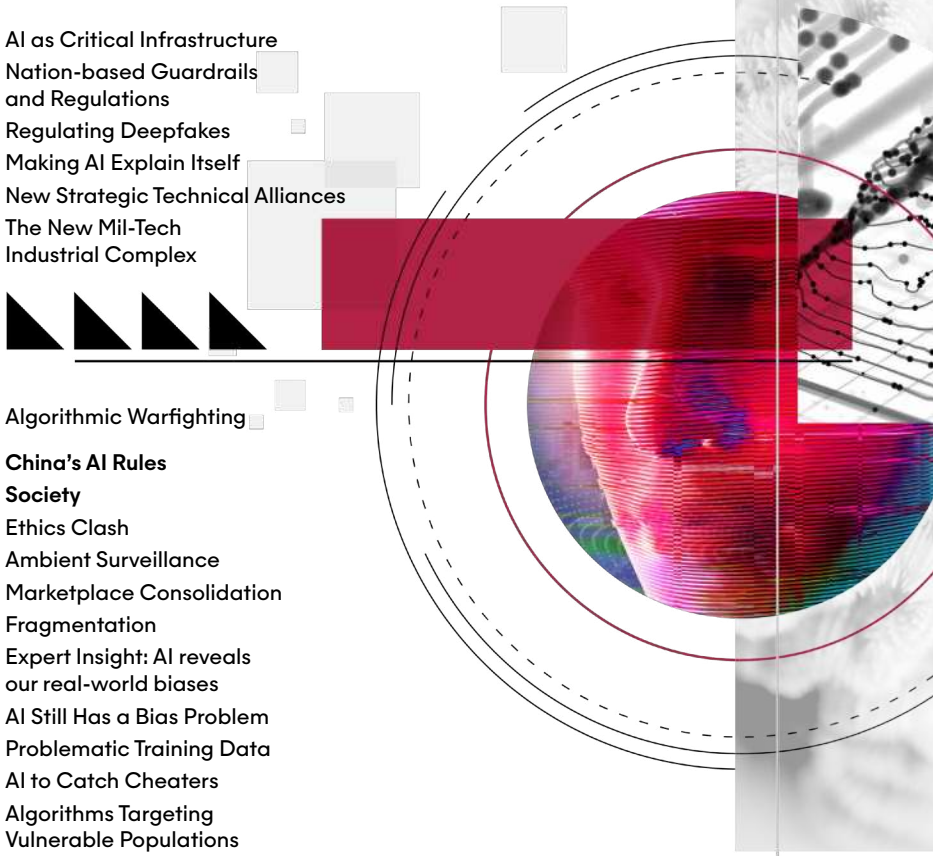

# Artificial Intelligence Summary

- Natural language processing is an area experiencing high interest, investment, and growth.
- No-code or low-code systems are unlocking new use cases for businesses.
- Amazon Web Services, Azure, and Google Cloud's low-code and no-code offerings will trickle down to everyday people, allowing them to create their own artificial intelligence applications and deploy them as easily as they could a website.
- The race is on to capture AI cloudshare—and to become the most trusted provider of AI on remote servers.
- The AI community still operates using a closed-source model. Researchers' reluctance to publish their full code leads to less transparency and reproducibility, and makes accountability murky.
- Natural language processing algorithms— typically used for text, words, and sentences—are being used to interpret genetic changes in viruses.
- COVID-19 accelerated the use of AI in drug discovery last year. The first trial of an AI-discovered drug is underway in Japan.
- AI plays key roles in synthetic biology, genetics, and medical imaging; predicting the spread of disease; and improving patient health outcomes.
- New artificial nervous systems use AI and neural implants.
- The SuperGLUE benchmark, which measures AI's human language ability, will likely be surpassed by the end of 2021.



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# Artificial Intelligence Summary

- Gaussian processes, the gold standard for many real-world modeling problems, are becoming more accurate and easier to train.
- AI researchers are leaving academia for corporations at an alarming pace.
- Generative adversarial networks assist artists and musicians in new forms of creative expression.
- A new wave of AI nationalism is rising as governments institute new restrictions on M&A and investment activity.
- Several countries will launch national AI strategies in 2021 and 2022.
- New measures to regulate the creation and distribution of deepfakes will be introduced throughout 2021 and 2022.
- Technical alliances that help drive future R&D could also challenge existing geopolitical alliances.
- Future wars will be fought in code, using data and algorithms as powerful weapons.
- We continue to fail to see China's growing AI proficiency as a military, economic, and diplomatic threat.
- New software could be viable for 100 years by using AI to adapt to changes around it.



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14TH YEAR ON THE LIST

# Artificial Intelligence

AI is a force multiplier for every industry.

## KEY INSIGHT

**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.**

## EXAMPLES

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 within the discipline that you should be following. You will also find the technology intersecting with other trends throughout this report.

## DISRUPTIVE IMPACT

The convergence of groundbreaking research, business use cases, the explosive growth of data, and improvements in computing power and storage are enabling advances in AI. The global artificial intelligence market is expected to grow at a compound annual growth rate of 42.2% from 2021 to 2027.

## EMERGING PLAYERS

- Broad Institute
- Clarifai
- Clearview AI
- DeepMind
- Disperse
- Graphcore
- HiSilicon Technologies
- Kasisto
- LabGenius
- Mohamed bin Zayed University of Artificial Intelligence
- Niantic
- Nvidia
- OpenAI
- OpenMined
- Persado
- PolyAI
- Recursion
- SenseTime
- Scale AI
- Syntiant



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# An Executive's Guide to AI

## What You Need To Know

In its most basic form, artificial intelligence is a system that makes autonomous decisions. AI is a branch of computer science in which computers are programmed to do things that normally require human intelligence. This includes learning, reasoning, problem-solving, understanding language, and perceiving a situation or environment. AI is an extremely large, broad field that uses its own computer languages and relies on computer networks modeled on our human brains.

## Machine Learning

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.

Machine learning uses data to make predictions and recommendations on how to achieve stated goals. Types of machine learning include supervised, unsupervised, and reinforcement.

**In supervised learning**, an algorithm uses training data to learn the relationship between established parameters—inputs and outputs. Humans supervise, tweaking and adjusting systems as they work. 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. Understanding what product features would most likely drive new purchases is an example of a business use case for supervised learning.

**In unsupervised learning**, data is provided to an algorithm without specific output parameters. For example, if a researcher doesn't know quite what to do with a large dataset, an algorithm 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 the virus is spreading throughout communities.

**In reinforcement learning**, an algorithm learns to perform a task by repeatedly running calculations as it attempts to accomplish a stated goal. Reinforcement learning 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

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 themselves. 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 models. The most common types include convolutional neural networks, recurrent neural networks, transformer neural networks, and generative adversarial networks (GANs).

**A convolutional neural network (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: anomalies in medical imaging, faulty products on a production line, blight on crops.


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# An Executive's Guide to AI

**Recurrent neural networks (RNNs)** are multilayered neural networks that 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).

**GANs** are unsupervised deep learning systems 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.

**A transformer** is a type of neural network architecture that learns what words mean when they appear in a particular context. Using "attention mechanism," 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 and generation.

## Weak and Strong AI

There are two kinds of AI—weak (or "narrow") and strong (or "general"). Narrow AI systems make decisions within very narrow parameters at the same level as a human or better, and we use them all day long without even realizing it. The anti-lock brakes in your car, the spam filter and autocomplete functions in your email, and the fraud detection that authenticates you for a credit card purchase—these are all examples of artificial narrow intelligence.

Artificial general intelligence (AGI) describes systems capable of decision-making outside of narrow specialties. Dolores in "Westworld," the Samantha operating system in "Her," and the H.A.L. supercomputer from "2001: A Space Odyssey" are anthropomorphized representations of AGI—but the actual technology doesn't necessarily require humanlike appearances or voices.

There is no single standard that marks the distinction between weak and strong AI. This is problematic for researchers covering AI developments and for managers who must make decisions about AI. In fact, we have already started to see real-world examples of functioning artificial general intelligence. In 2017, researchers at DeepMind, a lab owned by the same parent company as Google, announced that AI had taught itself how to play chess, shogi (a Japanese version of chess), and Go (an abstract strategy board game)—all without any human intervention. The system, named AlphaZero, quickly became the strongest player in history for each game. The team has been publishing important discoveries at an impressively fast pace. Last year, the DeepMind team taught AI agents to play complex games, such as the capture the flag "game mode" inside the video game "Quake III Arena." They, like humans, had learned skills specific to the game as well as when and how to collaborate with other teammates. The AI agents had matched human player ability using reinforcement learning, in which machines learn not unlike we do—by trial and error. While we haven't seen an anthropomorphic AI walk out of DeepMind's lab, we should consider these projects as part of a long transition between the narrow AI of today and the strong AI of tomorrow.


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# Enterprise

# Enterprise Trends

By measuring certain biomarkers, AI can detect people's emotions and respond accordingly.

## 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. In 2020, some of the fastest-growing GitHub projects were MLOps, or projects that dealt with tooling, infrastructure, and operations. Going forward, MLOps will describe a set of best practices that combines machine learning, traditional DevOps, and data engineering.

## 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's AutoML includes image classification, object detection, translation, and all sorts of pattern recognition tools. MakeML creates object detection. Applications have included tracking tennis balls during matches and automatically 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.

## 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.



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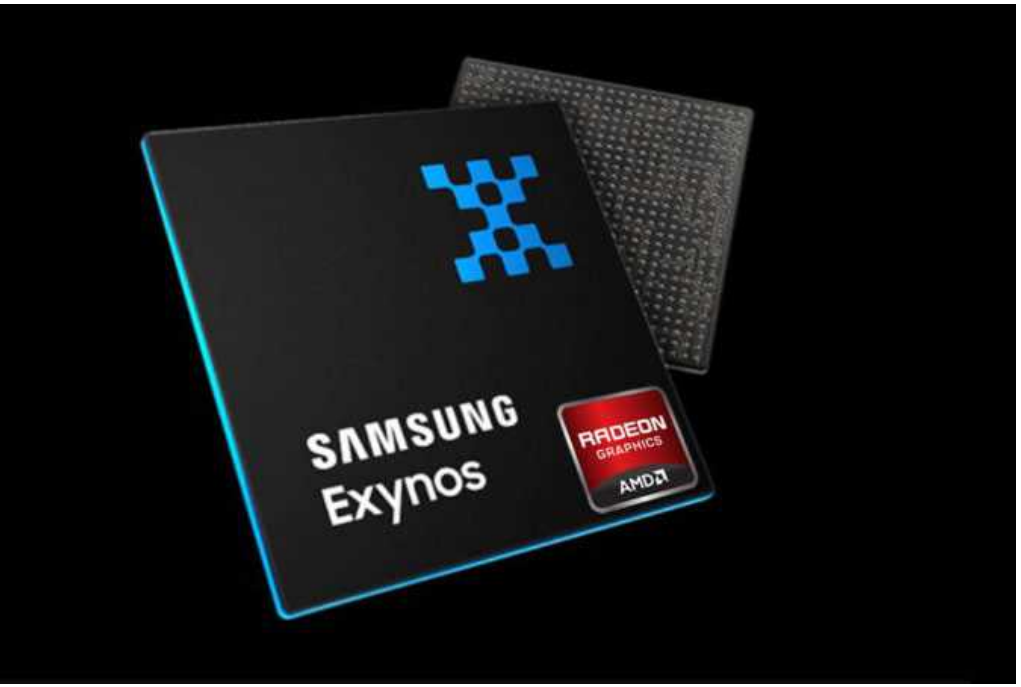
# Enterprise Trends




Samsung's next Exynos system on a chip will have an AMD graphics processing unit (GPU).

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.

## Artificial Emotional Intelligence

Research teams at Loving AI and Hansen Technologies 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 clinical therapy chatbot. By designing machines to respond with empathy and concern, digital assistants such as Alexa will increasingly become a part of one's family. This technology could eventually end up in hospitals, schools, and prisons, providing emotional support robots to patients, students, and inmates. According to health service organization Cigna, the rate of loneliness in the U.S. has doubled in the past 50 years. Two years ago, former U.K. Prime Minister Theresa May created a new cabinet position, the world's first Minister of Loneliness. 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.

## Serverless Computing

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.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# Expert Insight

## Emotion AI Will Power the Empathy Economy, but AI Still Needs to Work

**Dr. Rana El Kaliouby**

CEO of Affectiva

Emotion AI will power the empathy economy, but AI still needs to work.

The COVID-19 pandemic has meant that more than ever, we rely on video conferencing to connect virtually–working remotely, learning from home, and in our social lives. But there's a big problem: These technologies are emotion blind.

When we communicate in person, we convey so much more than the words we say: We express ourselves through nonverbal cues from our faces, voices, and body language. But technology is not designed to capture the nuances of how we interact with those around us.

AI may be the answer to preserving our humanity in virtual environments. Specifically, Emotion AI—software that can understand nuanced human emotions and complex cognitive states based on facial and vocal expressions—can address some of technology's shortcomings in light of the pandemic, and we'll see companies using it for new use cases, such as:

### 1. Video conferencing and virtual events

Emotion AI can provide insight on how people are emotionally engaging in a virtual event or meeting. This provides presenters with valuable audience feed-

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back, gives participants a sense of shared experience, and can help companies take a pulse on collective engagement during this stressful time.

### 2. Online learning

Emotion AI can give feedback on how students are engaging with online educational materials and lectures, flagging if they're confused, stressed, or bored. This becomes especially important during the pandemic as so many students are learning online and suffering from "Zoom fatigue."

### 3. Telehealth

Emotion AI can create more meaningful discussions and trust between patients and healthcare providers as telehealth appointments are replacing in-person visits. And, a data-driven analysis of a patient's emotional wellbeing provides a quantitative measure of mental health that goes beyond self-reporting on a rating scale of 1-10.

> AI researchers are now taking data that's already been collected and synthesized and using it to create brand new data.

### What's on the horizon for AI:

### 1. Data synthesis.

AI algorithms are built on deep learning, but they can only work accurately when they're trained and then validated on massive amounts of data. That includes data that are diverse and truly representative of the situations the algorithm will encounter in the real world.

But companies developing AI often are challenged in getting access to the right kinds of data and the necessary volumes of data. That's where data simulation and data synthesis methodologies will come into play, addressing those problems. AI researchers are now taking data that's already been collected and synthesized and using it to create brand new data.

Take the automotive industry. The industry seeks to develop advanced driver safety features and personalize transportation, and to achieve that car makers want to better understand what's happening with people inside of a vehicle. Getting that real-world data is difficult, expensive and time-consuming. But data synthesis is not. For example, a video of a person driving a car can become data that lets researchers create new scenarios, such as simulating the person turning her head, or wearing a hat or sunglasses.

### 2. The need for diversity, equity and inclusion.

As AI becomes more mainstream, the tech is taking on roles that were traditionally done by humans and changing how we interact with one another. For the technology to work for all of us, diverse teams must build those applications. Indeed, the number



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> Emotion AI can give feedback on how students are engaging with online educational materials and lectures, flagging if they're confused, stressed, or bored.

one issue to look out for is the risk for bias. Unfortunately, we've seen many instances in which AI has been biased against minority groups. Not only is this unethical; it's also bad for business. If AI can't work for all people as it's intended, there's little benefit to using it in the first place.

**3. The challenge of power asymmetry.**

Powerful technologies like AI are often in the hands of large corporations and governments, and this poses a number of challenges. The value that users receive from the technologies don't always measure up to the value that companies gain from the tech's user data. Also, those corporations or governments can determine a technology's distribution and who has access to it. This can have adverse implications for social and economic mobility. People with access to certain types of AI will be able to work more efficiently and will have a leg-up on those who don't have access. I worry about the impact this can have on communities and populations that are already disadvantaged, because AI could continue to widen that gap.

We need to create guidelines to ensure AI is applied in an equitable way. The technology has the potential to improve people's lives and solve societal problems, but if we don't start thinking about power distribution now, we risk institutionalizing AI in a way that may exacerbate inequalities.

**

*Dr. Rana El Kaliouby is the Co-founder and CEO of Affectiva, the pioneer of Emotion AI. Rana invented the company's award-winning emotion recognition technology. Prior to founding Affectiva, el Kaliouby was a research scientist at the MIT Media Lab where she spearheaded applications for facial coding to benefit mental health, autism, and other research areas. Born and raised in Cairo, she received degrees in computer science from the American University in Cairo and a Ph.D. from the computer laboratory, University of Cambridge.*



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## AI in the Cloud

Corporate leaders within the AI ecosystem have been racing to capture AI cloudshare—and to become the most trusted provider of AI on remote servers. Enterprise customers are likely to stick with their initial vendor, because 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. New York University Stern School of Business professor Arun Sundararajan says it best: "The prize will be to become the operating system of the next era of tech."

## 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.

## Advanced AI Chipsets

Today's neural networks have long required an enormous amount of computing power, have taken a long time to train, and have relied 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, Alphabet, IBM, Nvidia, Intel, and Qualcomm, as well as startups Graphcore, Mythic, Wave Computing, SambaNova Systems, 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. Cerebras has built 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. As of November 2020, Amazon's homegrown AI chip AWS Inferentia now powers Alexa's back-end services rather than chips designed by Nvidia. The AI chip market will quadruple to $6.7 billion in 2022, from $1.66 billion in 2018, according to market research firm Tractica. Marketing pretrained chips to businesses 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.

## Digital Twins

Digital twins are virtual representations of real-world environments, products, or assets for a variety of purposes. Manufacturers use digital twins to manage the performance and effectiveness of machines and plants, while city planners use them to simulate the impact of new developments and roads. The Singapore government uses them for urban operations. Siemens MindSphere supports digital twins for a number of industries. As low-code and no-code systems become more prevalent, companies should be able to build and deploy digital twins to simulate a wide array of processes, which will lead to reduced spending on modernization efforts.

## Spotting Fakes

In the past year, researchers showed how AI could be used to compose text so good that humans couldn't tell it was machine written. The team at 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


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# Enterprise Trends

**Facebook launched the first AI model that translates 100 languages without relying on English data.**
(Image credit: Facebook.)

Watson AI Lab and Harvard University developed the Giant Language Model Test Room (GLTR), 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.

## Natural Language Processing for ESGs

Companies are moving toward new environmental, social, and governance (ESG) criteria—a set of standards increasingly used by investors to evaluate their investments. ESG standards must be quantified and explicitly stated, but measuring performance can be difficult because many intangibles or abstract concepts are involved. Natural language processing is being used to identify, tag, and sort documentation from various sources about a company's ESG reputation (on issues such as labor practices, community impact, diversity, and inclusion).

## Intelligent Optical Character Recognition

An ongoing challenge is getting machines to recognize the various ways we express ourselves in writing. Optical character recognition (OCR) works in fixed, recognizable formats such as highway signs and the text from a book. But often, OCR isn't smart enough to recognize different fonts, unique notations, or spreadsheets with fields specific only to one company. Researchers are training AI systems to recognize patterns, even if they show up in unusual places. For example, the AWS Textract system now recognizes both text and context specific to a company or business unit.

## Robotic Process Automation

Robotic process automation (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. Google's Duplex is a good example; it's a bot designed to make routine phone calls. 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.

## Massive Translation Systems

In 2020, Facebook launched a new open-source AI language model called M2M-100 that can translate 100 languages. Facebook's AI lab trained the model using 7.5 billion sentence pairs gathered automatically from the web. (Surprisingly, Facebook did not use its own data for this project.) The FastText language model identified the language, and an unsupervised learning model matched sentences by their meaning. The goal was to improve simultaneous language translation.


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# Enterprise Trends

## 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 attackers 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 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.

## Global Rush to Fund AI

There is a global race to fund AI research and to acquire AI startups. In the first quarter of 2020, 285 U.S.-based AI startups had raised $6.9 billion, according to the National Venture Capital Association. Investment waned as Covid became a global pandemic, but tech giants including Apple, Google, and Microsoft are still acquiring AI companies, while non-tech companies are gobbling AI startups too: McDonald's acquired personalization platform Dynamic Yield, while Nike acquired inventory management company Celect and guided shopping experience platform Invertex.

## Algorithm Marketplaces

In the 2010s, big tech companies, startups, and communities of developers used algorithm marketplaces to share and sell their work. In 2018, Microsoft paid $7.5 billion to buy GitHub, a popular development platform allowing anyone to host and review code, to collaborate with other developers, and to build all kinds of projects. 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.) There are marketplaces for generalists, like GenesisAI and Algorithmia, where developers 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. Quantiacs allows developers to build algorithmic trading systems, and it matches their algorithms with capital from institutional investors. Bonseyes is a European-specific marketplace to buy and sell AI tools.

## 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.


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## Rage Against the Machine

**Mid-future neutral scenario**

From screaming into pillows to pounding punching bags, humans have developed numerous ways to air our frustrations. The hope is that if we act out against inanimate objects, we're less likely to act out against our fellow humans, risking harm or trauma. But what if there were a humanoid stand-in that could absorb our aggressions in a more cathartic, and ultimately beneficial way? As AI begins to achieve convincing emulations of human personalities, a new type of avatar emerges, algorithmically designed to provide a responsive therapeutic outlet for aggression.

Users can program the avatar to look and act like a figure from their life (a boss, a partner, a rival) for whom they harbor pent-up feelings, allowing users to express themselves freely without threatening their real-life relationships or risking legal repercussions. The AI persona could even be assigned to a surrogate robotic body, letting the user act out physical aggressions. But as the technology grows in popularity, designers must keep watch that what they've created  doesn't normalize and increase the rate of interhuman conflict, instead of alleviating it.

# Scenarios



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# Health, Medicine & Science

# Health, Medicine, and Science Trends

**The U.S. Food and Drug Administration approved IDx-DR, the first autonomous AI system to provide a diagnostic decision.**

## 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. 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, an algorithm determines what to change next. A 9- to 12-month process was completed in five days. Google's DeepMind developed a way of testing and modeling the complex folding patterns of long chains of amino acids, solving a problem that has vexed scientists for many years. DeepMind's system, 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 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


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# Health, Medicine, and Science Trends

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. Different 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 (KLG), 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

Radiologists and pathologists increasingly rely on AI to assist them with diagnostic medical imaging. Last year, new 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. In a trial, an AI screening system from Google Health and DeepMind outperformed human radiologists and reduced false positives in two large, clinically representative datasets from the U.S. and U.K.

## NLP Algorithms Detect Virus Mutations

Natural language processing (NLP) algorithms, which are typically used for text, 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 write words and sentences 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. Massachusetts Institute of Technology 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.

## Diagnostics Without Tests

The Covid Symptom Study—created by doctors and scientists at Massachusetts General Hospital, the Harvard T.H. Chan School of Public Health, King's College London and Stanford University School of Medicine, and health science company ZOE—developed an app to study Covid symptoms and track the spread of the virus. It collects and uses AI to analyze data from 4 million global contributors to discover new symptoms, predict Covid hot spots, and eventually predict Covid cases without physical tests.

## Protein Folding

In November 2020, DeepMind's AI made a big announcement: It successfully determined a protein's 3D shape from its amino-acid sequence. The program, AlphaFold, outperformed an estimated 100 teams in a biennial protein-structure prediction challenge called Critical Assessment of Structure Prediction (CASP). Predicting protein structures has long vexed biologists. AlphaFold had previously bested other teams, but it worked so quickly and so accurately at last year's CASP that it signaled a near future when the technology could be used regularly by other scientists.

## 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


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# Health, Medicine, and Science Trends

AI is used to increase the speed and efficiency of new drug discovery.

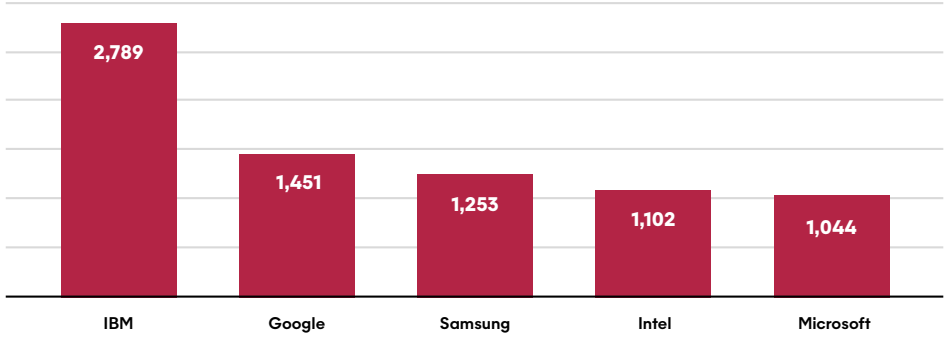
their data was fed into a computer that looked for patterns. Scientists verified a state of REM sleep, and then participants interacted with researchers using eye movements. The study proved that there are new ways to send and receive real-time information while dreaming.

## 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.

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. The number of patents with deep neural networks grew 67% between 2016 and 2020, making it the top technology mentioned.

**Leading Applicants, 2016–2020**




Source: IFI Claims Patent Services, January 2021 study.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## Deep Twins in the OR

### Mid-future optimistic scenario

The success rate of complicated medical procedures skyrockets when hospitals construct AI-enabled digital twins of patients. These virtual facsimiles mirror the exterior and interior structure of the patient's living body, as well as its real-time bodily functions, thanks to ultra-high fidelity mapping technology. Doctors are thereby able to virtually "operate" on the digital twin, using sophisticated AI to simulate outcomes and determine the safest and most effective approach to surgery, minimizing risk to the patient's life and well-being. Should a complication arise, the algorithm adjusts and adapts the recommended course of action based on the new data—in cases of extreme emergency, the AI can even take over and automate certain surgical tasks. The patient experience is revolutionized and the statistical risk of operations is drastically reduced, making trips to the OR feel more like a routine doctor's visit.

# Scenarios



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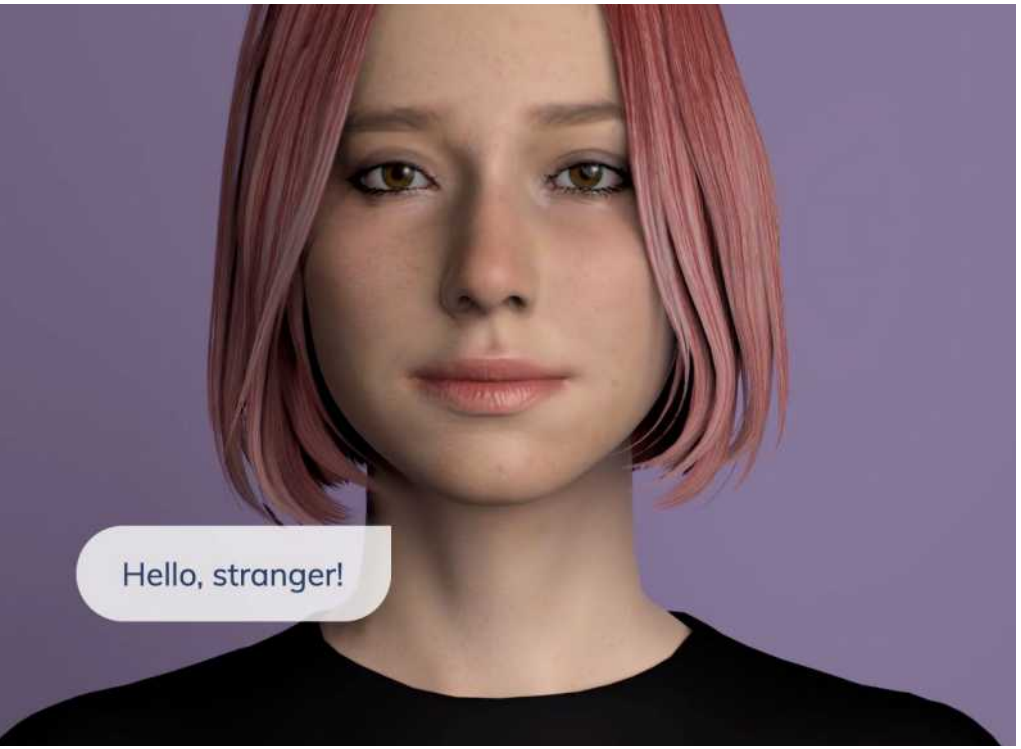
# Consumer

# Consumer Trends




Replika is a programmable digital twin that you can deploy for your friends.

## Zero UIs

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 or not 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.

## 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

Digital assistants (DAs)—like Siri, Alexa, and their Chinese counterpart Tiān Māo 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's Duplex, Tiān Māo 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 model correctly projected that nearly half of Americans would own and use a digital assistant by 2020. (An estimated 62% of Americans 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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# Consumer Trends

Alibaba's voice assistant uses natural language processing.

card companies, banks, local authorities, political campaigns, and many others can harness DAs to both surface and deliver critical information.

## Deepfakes for Fun

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.


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# Research

# Research Trends

## 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 15% of all academic papers on AI publish their full code, and some big names—DeepMind and OpenAI—notoriously leave theirs out, citing proprietary concerns.

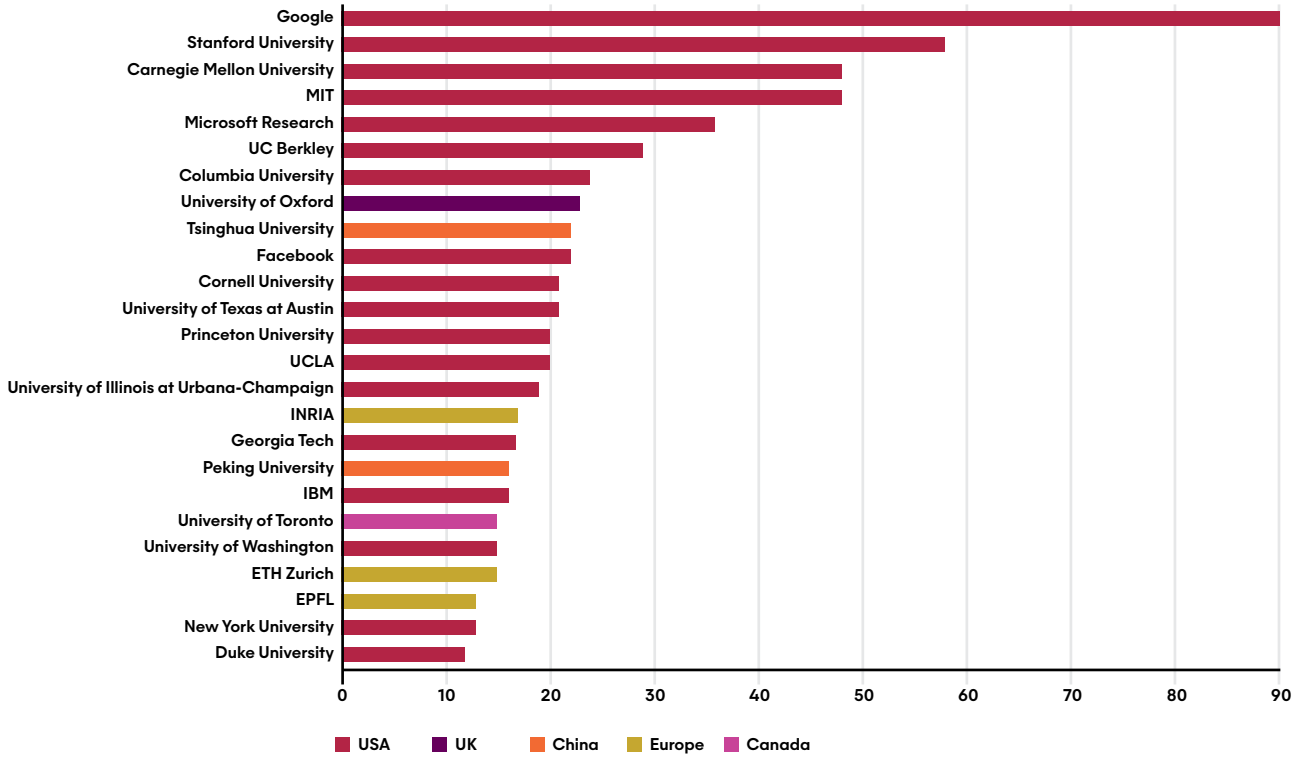
## Framework Consolidation

Google's TensorFlow and Facebook's PyTorch are two popular frameworks used by researchers, and the relative popularity of different frameworks typically mirrors trends in the commercial application landscape. In the past four 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.

## 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 1000 parameters. OpenAI's 175 billion parameter, 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 pre-train and publish big models.

Most Active Institutions for AI Research




Papers published at NeurIIPS 2019 (fractional count)

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



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# Research Trends

## 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 nine sentence- or sentence-pair language-understanding tasks 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 leaderboard. We predict that by the end of 2021, this new benchmark will also be surpassed.

## Machine Reading Comprehension

For AI researchers, machine reading comprehension (MRC) has been a challenging goal, but an important one. MRC makes it possible for systems to read, infer meaning, and immediately deliver answers while sifting through enormous datasets. In 2019, China's Alibaba outperformed humans when tested by the Microsoft Machine Reading Comprehension dataset (or MS MARCO for short), which assessed its ability to use natural language to answer real questions posed by humans. Alibaba's system delivered answers to search queries posted by people to Microsoft's Bing, such as "How many carbs are in an English muffin?" and "How do you grow hops?"

## AI Summarizing Itself

A new AI model can summarize scientific literature, including research about itself. The Allen Institute for Artificial Intelligence (AI2) 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.

## 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 multi-task 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.

## 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.

## Federated Learning

Federated learning is a technique that distributes machine learning to the edge. Introduced by Google researchers in 2016, it is a new 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.

## GP Models

Gaussian processes (GP) are the gold standard for many real-world modeling problems, especially in cases where a model's success hinges on its ability to faithfully represent predictive uncertainty. GPs are becoming more accurate and easier to train, benefiting from neural network improvements.

## GPT-3's Influence

The enormous AI that generates human-like language, GPT-3, was released by OpenAI last year. The text generator has written blog posts and code. It was pitted against college students in an essay writing contest, and the anonymized


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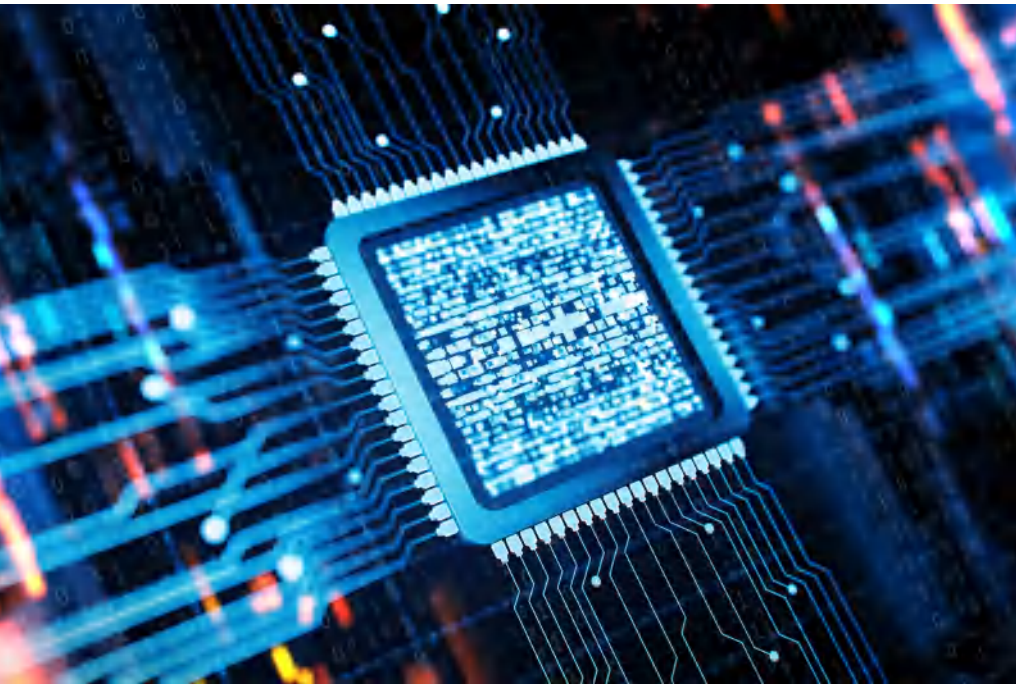
# Research Trends



The SuperGLUE benchmark will be broken by the end of 2021.

papers were graded by professors. GPT-3 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.

## 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.

## 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 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 autocompleted him wearing a suit. The system autocompleted women—including U.S. Rep. Alexandria Ocasio-Cortez (D-N.Y.)—wearing a low-cut top or bikini 53% of the time.

## Predictive Models Using Single Images

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



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# Research Trends

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.

## 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.

## Real-time Machine Learning

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 real-time machine learning (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.

## 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. Automated machine learning, or AutoML, is a new approach: a process in which raw data and models are matched together to reveal the most relevant information. Google, Amazon, and Microsoft now offer a host of AutoML products and services.

## 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, a technology company specializing 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. Pandora leverages both human and system-generated observations to explain malfunctions related to input content and system architecture.

## 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.

## 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 grandmaster, has developed an innovative new algorithm: AlphaZero. It is capable of achieving superhuman performance not only in


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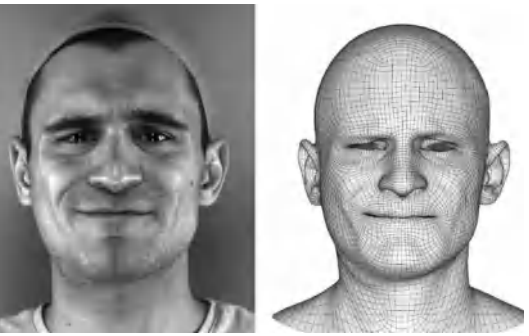
# Research Trends



Using AI, researchers automated the task of converting live actor performances (left) to computer game virtual characters (right).

Go but in other games as well, including chess and shogi (Japanese chess). This one algorithm starts with no knowledge except for the rules of the game and eventually develops its own strategies to beat other players. In January 2020, DeepMind published new research showing how reinforcement learning techniques could be used to improve our understanding of mental health and motivation.

## 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.

## 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 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.

## Proprietary, Homegrown AI Languages

Python is a leading language with lots of pre-built libraries and frameworks. Julia, a language developed by Massachusetts Institute of Technology, is an open-source language that focuses on numerical computing. And of course there's Lisp, created by modern AI's foreparent John McCarthy in 1958. Companies are starting to build and release their own software packages now, as well as unique programming languages for AI applications. Uber released its own probabilistic programming language, Pyro, which it wrote in Python. It's a move that signals likely fragmentation in the future of the AI ecosystem, not unlike the current iOS/Android rivalry or the long Mac/PC war. Businesses will find it increasingly cost-prohibitive and difficult to switch between AI frameworks and languages.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# Talent

# Talent Trends

The Mohamed bin Zayed University of AI opened in the United Arab Emirates last year.

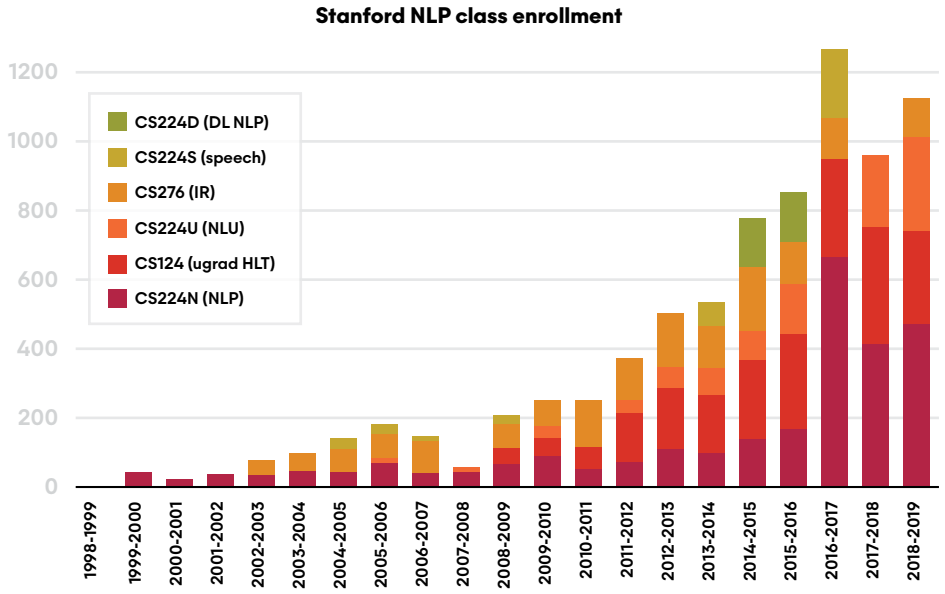
## AI Brain Drain

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. Google, DeepMind, Amazon, and Microsoft hired 52 tenured and tenure-track professors from U.S. universities between 2004 and 2018. In return for their poaching, tech companies are endowing AI professorships at top universities. In some cases, professors 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. Facebook has aggressively hired superstars like New York University professor Yann LeCun and Carnegie Mellon professor Jessica Hodgins. Poaching departments today could rob the future of future AI experts: Without great scholars, who will train the next generation of innovators?

## AI Universities

Interestingly, new institutions solely focused on AI are launching around the world and offering postsecondary education. In the United Arab Emirates, the Mohamed bin Zayed University of Artificial Intelligence launched last year. MBZUAI is the world's first graduate-level, research-based AI university. Based in Abu Dhabi, it offers master of science in computer vision and Ph.D. programs in AI-related fields. Founded by Harvard University and University of California–Los Angeles faculty, Univ. AI is an online program for training in machine learning and AI.

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




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



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# Talent Trends

"I have always been convinced that the only way to get artificial intelligence to work is to do the computation in a way similar to the human brain. That is the goal I have been pursuing. We are making progress, though we still have lots to learn about how the brain actually works."

— Geoffrey Hinton

## Demand for AI Talent Growing

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, according to a 2020 Reuters study. Demand has also driven up wages. A recent study from Glassdoor estimated that average annual salaries for AI-related jobs rose 11% between 2017 and 2018 to $123,069.

## Corporate AI Labs

AI labs are located around the world, with concentrations in North America, Europe, and Asia. Facebook, Google, IBM, and Microsoft operate 62 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 companies to overcome that barrier. Most of those labs do basic AI research rather than product development. The G-MAFIA—Google, Microsoft, Amazon, Facebook, IBM, and Apple—spend $76 billion on R&D annually. Collectively, their market cap exceeds $6 trillion.

## AI for Interviews

Recognition systems can now be deployed to watch you being interviewed and to gauge your 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—in a store, 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.



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# Creative

# Creative Trends

**Creative studio SoKrispyMedia develops short films featuring stick figures in battle. It relies on real-time rendering for photorealistic results.**

Image credit: Nvidia.

## 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. Last year, 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

Last year, the creators of "South Park" built an entire show using deepfakes. "Sassy Justice" aired on YouTube and featured a synthetic reporter, Fred Sassy, who looked a lot like former President Trump—with just a different enough voice and hairstyle to evade legal challenges. Episodes featured deepfakes of Al Gore, Mark Zuckerberg, Jared Kushner, and others. The open-source algorithm DeepFaceLab has been used by other artists and filmmakers. There was a Hulu commercial deepfaking sports stars, and several 2021 Super Bowl commercials, including an eerie appearance by Vince Lombardi, used deepfakes and synthetic media. 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 and others.

## Generating Virtual Environments from Short Videos

Chip designer 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.



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# Creative Trends

Jukebox is a neural net that generates music, including rudimentary singing, as raw audio in a variety of genres and artist styles.

## Automated Versioning

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 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. There's obviously a dark side to this technology, however. Last year, 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.



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# Geopolitics & Defense

# Geopolitics and Defense Trends

Cyber warfare will change the art of war in the coming decade.

## 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. In 2020, Germany passed a law to allow the government to review or block investments or takeovers of robotics, AI, and semiconductor companies by non-EU–based firms. The foreign ownership threshold also dropped to 10% from 25%. The U.K. similarly strengthened its foreign investment policies for AI: Any M&A activity involving AI companies in which revenue exceeds 1 million pounds requires government scrutiny. Many acquisitions are being blocked as a result. The U.K. and U.S. blocked a takeover of Imagination Technologies by China's Canyon Bridge last year. A bipartisan bill proposed in the Senate, known as the Endless Frontier Act, explicitly frames AI as a race between the U.S. and China. 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.

## National AI Strategies

A new wave of countries will launch national AI strategies in 2021 and 2022. Iceland, Norway, Kenya, Chile, Colombia, and New Zealand are all developing national 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 collaboration and coordinated efforts to streamline goals, outcomes, R&D efforts, and funding.

## 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.


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# Geopolitics and Defense Trends

## Nation-based Guardrails and Regulations

From self-driving car accidents to election 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 now 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. Last year, China moved into position to lead the first set of global AI norms and standards. In 2019, the country published a report on technical standards that would allow companies to collaborate and make their systems interoperable. The EU and the Organisation for Economic Co-operation and Development similarly published their own guidelines, and the Trump administration signed an executive order to spur the development of standards in the U.S. 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

New measures to regulate the creation and distribution of deepfakes will be introduced throughout 2021 in the U.S. and elsewhere. A bill in Hawaii's state legislature seeks to prohibit unauthorized deepfake apps and tools. If it passes, deepfaking would be considered a Class C felony. Bills have also 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.

## The New Mil-Tech Industrial Complex

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. Plus, there is a lot of money to be made. The U.S. General Services Administration and the Department of Defense's Joint Artificial Intelligence Center recently 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. Both Amazon and Microsoft made headlines


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# Geopolitics and Defense Trends

U.S. Rep. Ro Khanna (D-Calif., pictured here), along with U.S. Sens. Todd Young (R-Ind.) and Chuck Schumer (D-N.Y.), and U.S. Rep. Mike Gallagher (R-Wis.), unveiled the bipartisan, bicameral Endless Frontier Act.

over a $10 billion, 10-year government tech contract called the Joint Enterprise Defense Infrastructure, or JEDI. Others, including IBM, Oracle, and Google, also competed to transform the military's cloud computing systems. Meanwhile, the CIA awarded Amazon a $600 million cloud services contract, while Microsoft won a $480 million contract to build HoloLens headsets for the Army. The contracts prompted employee protests. In 2017, the Department of Defense established an Algorithmic Warfare Cross-Functional Team to work on Project Maven—a computer vision and deep learning system that recognizes objects from still images and videos. The Department of Defense contracted Google to train the AI systems to analyze drone footage, but it turned out the Googlers assigned to the project didn't know they were doing military work. 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."

## Algorithmic Warfighting

Future wars will be fought in code, using data and algorithms as powerful weapons. The current global order is being shaped by artificial intelligence, 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. Israel uses autonomous drones for border patrol, while China developed stealth drones capable of autonomous airstrikes. 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.



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# China's AI Rules

President Xi Jinping has foregrounded AI as a major, long-term priority in China.

**If you think of China as a country that copies rather than innovates, think again.**

China is a 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.

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

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 Chinese 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 three 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 firms expect IP as well. China-based AI startups now account for nearly half of all AI investments globally.

## 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 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.



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# China's AI Rules

In 2020, numerous reports of abuse revealed that China turned its AI on the ethnic Uighur Muslim community. Huawei developed special AI software to identify Uighurs 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 Uighur 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.

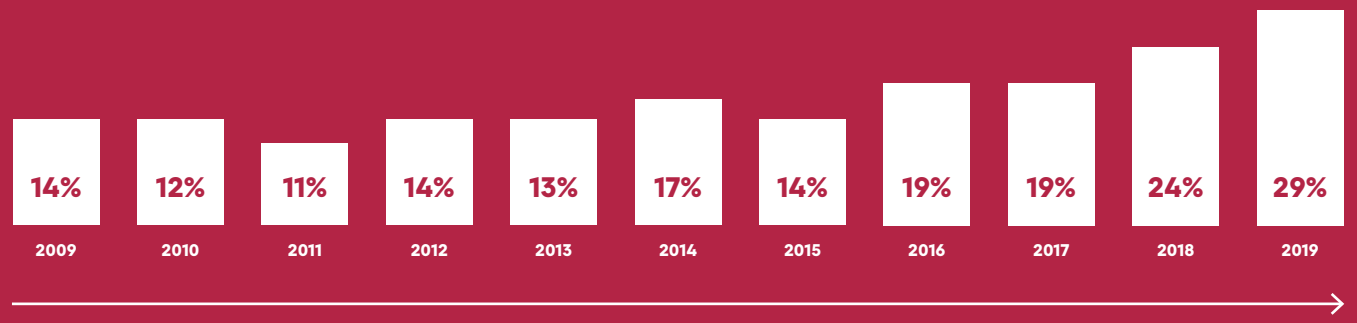
China is quietly weaponizing AI, too. China's People's Liberation Army is catching up to the U.S. military, using AI for such tasks as spotting hidden images with drones. The Chinese military is equipping helicopters and jet fighters with AI. The government created a top-secret military lab—a Chinese 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.

## The bottom line

There is a Chinese proverb that roughly translates to "forewarned is forearmed." Now that you know what's coming, reframe your thinking of China as simply the world's factory.

## Chinese-educated Researchers Dominate NeurIPS

Chinese-educated researchers dominated the papers accepted at NeurIPS, a prestigious international AI conference, according to a new study from MacroPolo, a think tank based at the Paulson Institute, which promotes constructive collaborations between the U.S. and China. Nearly one-third of the papers accepted were from China—more than from any other country.




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



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# Society

# Society Trends

**Timnit Gebru is a pioneering researcher on algorithmic bias.**

Image credit: Wikimedia Commons.

## 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. Google's head of AI, Jeff Dean, expressed his regret in an email to staff. 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 content.) 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. We anticipate many more ethics clashes in 2021.

## Ambient Surveillance

What happens behind closed doors may not be secret for long, and executives should beware 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.

## Marketplace Consolidation

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 nine 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 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.

## Fragmentation

The AI ecosystem spans hundreds of companies. They are building the network infrastructure, the custom chipsets, the consumer applications, the back-end communications systems, the low-power radios in our smart home gadgets … we could go on. Meanwhile, a large number of policy groups, advocacy organizations, and governments are developing guidelines, norms and standards, and policy frameworks hoping to guide the future development of AI. As a result, the ecosystem is fragmented in two ways: infrastructure standards and governance.



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# Expert Insight

## AI reveals our real-world biases

**Meredith Broussard**

Associate Professor,
New York University

The biggest topic of conversation in AI right now is bias. We're moving away from the stage of marveling at AI technology, and people are realizing that AI models and automated systems reproduce all of the existing biases and inequalities of the real world.

If your company is using AI, ask: how might this system fail, and for whom? If you are in a heavily-regulated industry, AI is a compliance risk. Educate your teams about algorithmic bias, audit your systems and your algorithms for bias, and require your vendors to do the same. If an AI system discriminates or makes decisions that are not in line with your corporate values, don't use it.

> The biggest topic of conversation in AI right now is bias.

**

*Meredith Broussard is an associate professor at the Arthur L. Carter Journalism Institute of New York University, an Affiliate with the New York University Alliance for Public Interest Technology, and the author of* ***Artificial Unintelligence: How Computers Misunderstand the World.***

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# Society Trends

## AI Still Has a Bias Problem

It's no secret AI has a serious and multi-faceted 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, you 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 your 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. You, or someone you know, could wind up on the wrong side of the algorithm and 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.

Increasingly, data is being harvested and sold to third parties without your knowledge. These biases can reinforce themselves over time. As AI applications become more ubiquitous, the negative effects of bias will have greater impact. The Apple card gave higher credit limits to men than women, in some cases by a factor of 20. Wearables such as Google's Fitbit are considerably less accurate for darker skin types because of how melanin absorbs green light. This can lead to bias when insurance company algorithms take into account heart rates, blood pressure, and risk rates for conditions like irregular heartbeats or a potential heart attack.

## Problematic Training Data

In 2018, researchers at MIT developed an AI called Norman that was trained to perform image captioning. They trained Norman using only 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 pre-trained 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.

## AI to Catch Cheaters

AI is being used to catch cheaters. ECRI Institute's CrossCheq uses machine learning and data analytics to look for hyperbole and misleading information during the hiring process. Drexel University researchers built an app that uses biometrics to predict when dieters are likely to stray from their prescribed regimens. Researchers at the University of Copenhagen created a machine learning system to spot cheating on essays with, they say, a 90% accuracy rate.

## 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


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# Society Trends

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, which was 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 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 moment, 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.

## Digital Dividends

Artificial intelligence will inevitably lead to a shift in the global workforce, causing job losses across many industries. Researchers at Oxford University's Institute for Humanity, researchers at the Future Today Institute, and former U.S. presidential candidate Andrew Yang have all published works outlining different versions of a "digital dividend"—a way for companies to pay back to society a portion of the profits derived from AI.

## 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 algorithms 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.


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## Bully Bots

### Mid-future pessimistic scenario

We've seen affable chatbots inadvertently turn malicious and inflammatory when they're exposed to unfiltered online conversations, but now they're purposely programmed to antagonize. Black hat hackers cultivate bully bots—malicious chatbots that target and troll children and teens. Bully bots are designed to detect and exploit children's insecurities to inflict harm and suffering, and they can be bought anonymously at low cost. With so much of younger generations' conversations taking place via texts and DMs, there is ample data to feed the chatbots so that they can easily impersonate their target's peers. Ill-intentioned kids—and, disappointingly, adults—use these bots to outsource cyberbullying and deflect guilt and responsibility from themselves. Opportunist criminals use them to threaten children of prominent figures and wealthy individuals to gain access to security information and valuable objects. With inadequate laws and frustrating layers of anonymity, parents are at a loss over how to prevent harm and seek justice for their victimized children.



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# Application

## STRATEGY

Artificial intelligence affects every business across multiple dimensions. AI is a cornerstone of most organizations, from workforce automation to digitization to staff allocation and beyond. 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 develop longer-term plans and 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.

## INNOVATION

AI is additive to the innovation and creative processes. Innovation teams can use deep learning for new product ideation, for understanding markets, and for anticipating what's on the horizon. Especially as no-code and low-code applications become more widely available, innovation teams will build powerful systems for decision management, general brainstorming, and powerhouse ways of generating new ideas.

## R & D

For AI companies, talent retention is likely to get worse in 2021, as companies offer increasingly competitive packages to attract top minds. China has emerged as an R&D powerhouse, posing additional talent challenges. But for other companies, this is a good time to make use of commercially available and open source frameworks, algorithms, cloud-based systems, and applications to mine your own data. There is tremendous value in learning from your customers, partners, and vendors, and industry.

## RISK

Risks abound in AI. New regulations could curb research, innovation, and product development. Geopolitical tensions and AI nationalism will start to direct foreign investment in new ways. Bias in facial recognition should concern everyone; so should the quickening advancements of general adversarial networks as they are used to manipulate and generate content. Everyone working in risk must develop a sharp focus on AI. Risk models should be developed to determine plausible near-future scenarios, so that leaders can adjust their strategies accordingly.



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# 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 about technology, science, and policy:

1

How well do we understand AI?

What opportunities are we leaving on the table?

2

Are we adequately planning for the long term?

What assumptions must hold true for our current strategy to succeed?

How will we make needed changes?

3

What parts of our business model make us vulnerable to disruption brought by the evolution of AI?

What can we do now to mitigate future risk?



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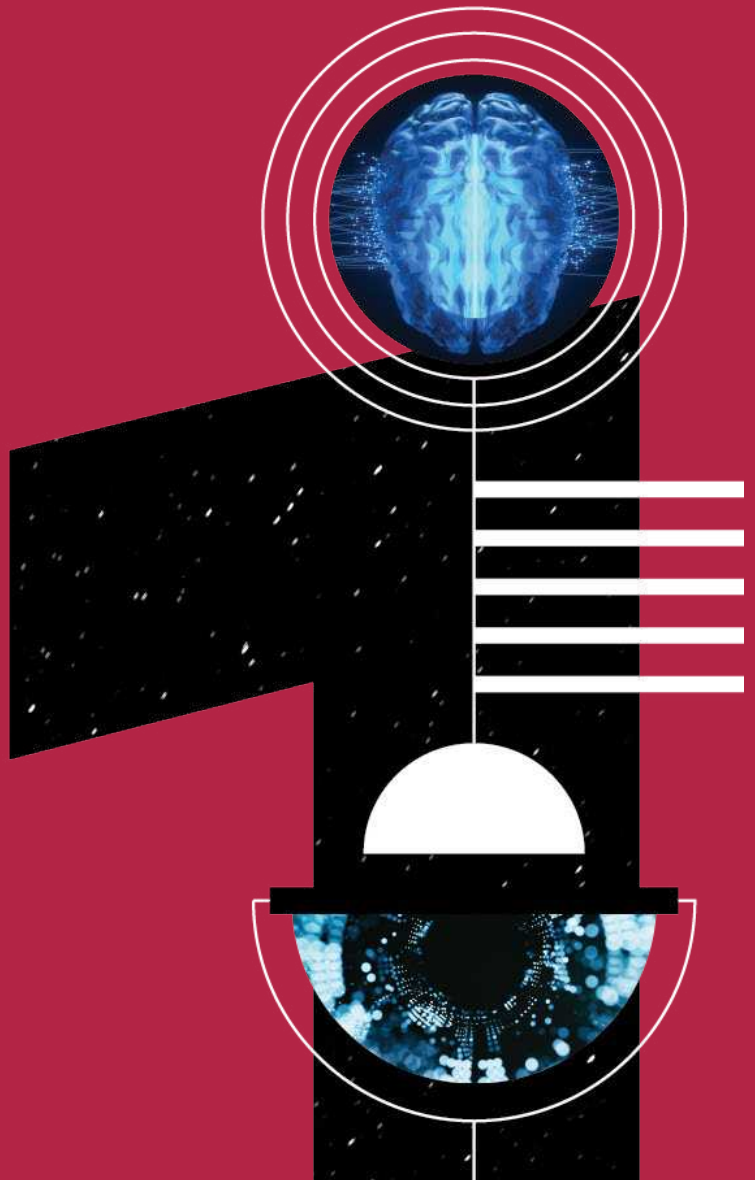

Future Today Institute

Volume 2 of 12

14th Annual Edition

# 2021 Tech Trends Report

Strategic trends that will influence business, government, education, media and society in the coming year.

## Scoring
## Recognition

Future Today Institute

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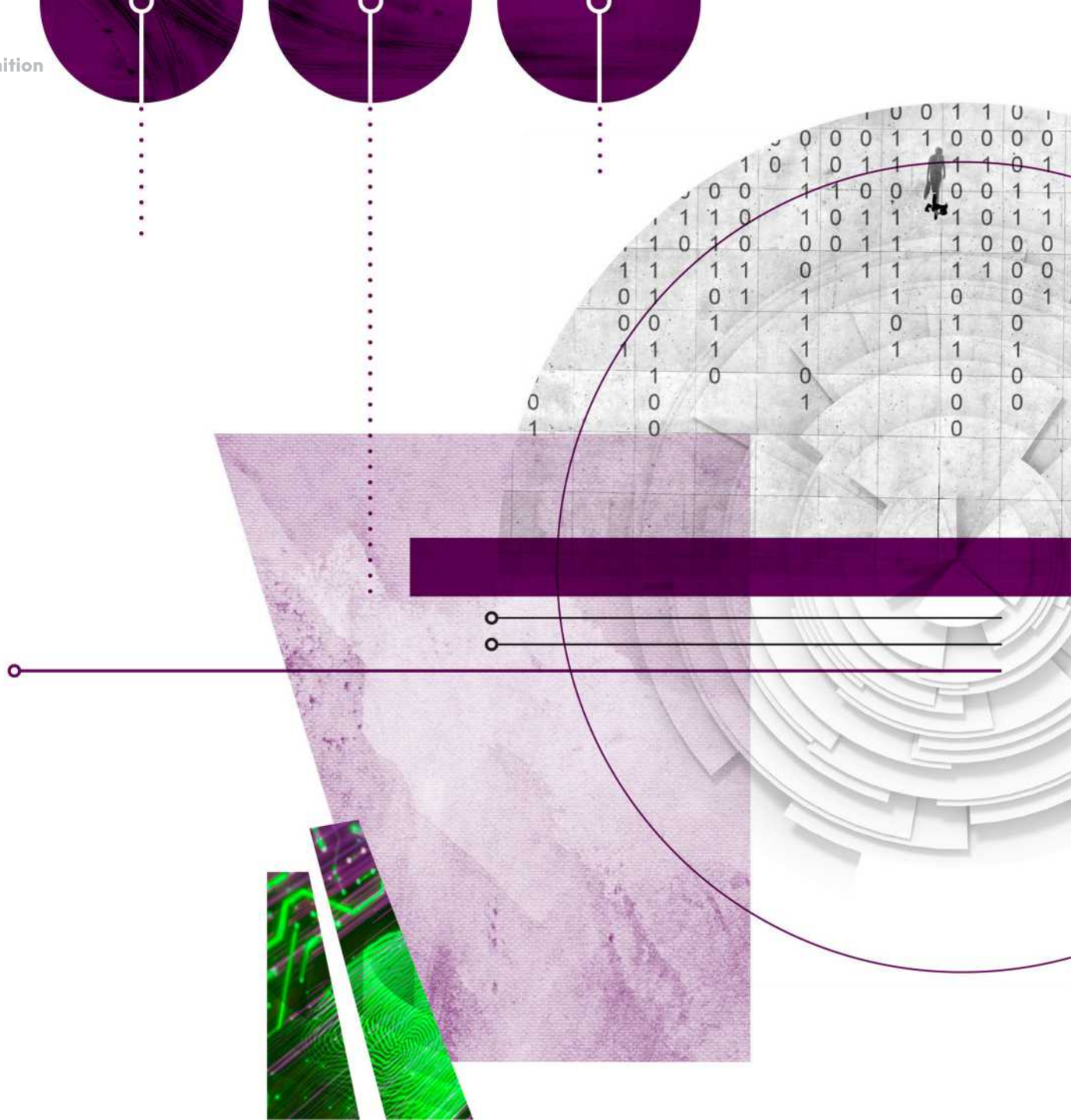

# Scoring & Recognition Summary

- Anonymity is dead.
- Voice assistants can guess what people are typing on nearby devices.
- Facial recognition systems now automatically identify people, pets, and even Disney characters.
- It's becoming easier for machines to "see" an object without a camera.
- New fabrics and compounds are being developed to help people fool recognition algorithms and, somewhat paradoxically, help them be seen more clearly.
- COVID-19 accelerated the adoption of universal genetic databases.
- Everyone alive today is being scored.
- A piecemeal approach to regulation will challenge businesses this year.



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# Recognition

5TH YEAR ON THE LIST

# Recognition

Intel RealSense ID processes all facial images locally.

Image credit: Intel.

## 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, or fingerprints—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 their next offense. 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

While there are now some recommendations in place to ban facial recognition systems, your face isn't your only biomarker. You can be recognized using thousands of personally unique data points. Recognition technologies aren't necessarily nefarious; they have many positive use cases, ranging from fraud detection to genome sequencing. 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 such efforts gaining momentum in the U.S. and Europe.

## EMERGING PLAYERS

- Dr. Dina Katabi, professor at Massachusetts Institute of Technology and director of NETMIT
- Electronic Frontier Foundation (EFF)
- 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
- Center for Democracy and Technology
- Joy Buolamwini, research assistant at the MIT Media Lab
- Hoan Ton-That, CEO of Clearview AI



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# Recognition Trends

**Manually annotated facial detection methods are applied on Disney Junior's Princess Elena of Avalor and Migs, a magical flying creature.**

Image credit: PyTorch.

## Faceprints

Our faces each have unique contours, bone, capillary and muscular construction, and physical characteristics and pigments that are specific to each one of us. Even identical twins aren't truly carbon copies of each other—they have thousands of tiny, potentially even imperceptible, differences. Just as we each have unique fingerprints, we also have unique faceprints. When a recognition system scans a human face, it can be used to identify people based on their biometric features. Intel's RealSense depth-sensing camera uses a neural network to detect a face and authenticate someone with only a glance. It adapts to users' faces over time and can still ID someone if they change their facial hair or wear glasses. China's Alipay uses faceprints to authenticate people's identities as they make purchases. Shanghai-based Fudan University and Changchun Institute of Optics, Fine Mechanics, and Physics (of the Chinese Academy of Sciences) developed a 500-megapixel facial recognition camera that can capture "thousands of faces at a stadium in perfect detail and generate their facial data for the cloud while locating a particular target in an instant." In practice, this means that a stadium can be scanned and, within seconds, produce a high-resolution image of every single face for recognition algorithms. Researchers in Japan and China are working on representation models that require only a portion of a person's face, even in low light, to accurately predict his identity—even if he changes his hairstyle, gets plastic surgery, or grows a beard.

## Facial Recognition for Animation

Powerful artificial intelligence (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, called Content Genome, populates knowledge graphs with metadata. Algorithms use that data for search, discovery, and personalization. For example, if an animator is working on a new movie adaptation of "Phineas and Ferb" and needs a particular evil machine made by Dr. Doofenshmirtz, she needs to type in just a few words to pull up all scenes where it appeared. 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 the windshield, mouths on the bumpers, and no noses.

## Voiceprints

Just as each person has a unique set of face characteristics, our voices also contain various measurable characteristics that uniquely identify us. Smart Bluetooth speakers like the Amazon Alexa-enabled Echo use voiceprints to recognize different people within the same space. Researchers, using new



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# Recognition Trends

Paris Hilton wears a camouflage scarf made of nano-spherical crystals that reflect light.

machine learning techniques and vast datasets of recorded voices, can listen to the micro-signatures in our voices and accurately identify us. Researchers at Carnegie Mellon University discovered a generative technique to build a 3D version of someone's face using only their voiceprint. Law enforcement agencies now use the system to identify prank callers in a practice known as "swatting," when people's false claims prompt local agencies to unwittingly deploy emergency crews to nonexistent emergencies.

## Accent Recognition

We rarely speak using standard, perfect language, and that poses a problem for voice recognition. Depending on where you're from in the U.S., the brown, fizzy, caffeinated beverage you drink from a can might be called soda, soda pop, pop, or Coke, even if what you're drinking is a Dr Pepper. Even if a common word is used, it might not sound the same. "Caramel" is pronounced "car-ml" in Colorado and "carra-mel" in Maine. Historically, voice recognition systems have struggled with accents or dialects, but that's finally starting to change. Tmall Genie, Alibaba's digital assistant, is being trained to recognize some of China's many regional dialects. Amazon is similarly training Alexa to recognize accents and dialects as well as ethnic origin.

## Automatic Voice Transcription

Plenty of practical applications exist for automatic voice transcription: recording meeting minutes, taking lecture notes, generating transcriptions for podcasts and shows, and serving medical and pharmacological teams as they work with patients. Otter.ai is a real-time voice transcription tool that understands accents and learns to recognize voices with repeated use. Google's Recorder app uses AI to automatically recognize and transcribe voices with near-perfect accuracy. Available only on Google's Pixel phones, the app can recognize specific conversations, which means that cross talk and background noise won't affect the transcription. Amazon Transcribe Medical automatically converts speech used in medical settings into text.

## Voice Cloning

With a large enough corpus of recorded speech, machine learning algorithms can be used to train a new voice model, often resulting in speech that's indistinguishable from the original speaker. Anyone who has ever recorded a podcast is familiar with editing challenges, such as guests talking over each other, random sirens blaring, or moments when a speaker sneezes or coughs. It 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. Respeecher and Resemble.ai are no-code platforms to create clones, although GitHub has plenty of open-source text-to-speech modeling systems, too. There's a dark side to this technology, however. Last year, hackers used voice cloning tools to trick an employee into thinking he was speaking on the phone to his CEO—and the employee then transferred $243,000 to a scammer's bank account.

## Emotion Recognition

Alexa doesn't just know who you are—she now knows how you're feeling. In 2018, Amazon filed a patent for a new system that detects the physical and emotional well-being of users based on their previous and current interactions. Its Rekognition suite (used by outside businesses and organizations) can now see fear in our faces, while Alexa can sense and understand frustration. Last year, Amazon launched the Halo, a voice-activated wearable that decodes how the user is feeling. (We described this, pre-launch, in last year's Tech Trends Report.) A real-world use case for the technology: Paired with smart earbuds, Alexa could advise the wearer in real time how to interact more effectively with others.



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# Recognition Trends

## 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 in 2018, 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 specific needs and desires. Electronic Arts is working on a system that assesses the personality of its multiplayer video game users and ultimately does a better job of matching players, using their play style, conversational style, and willingness to spend money as criteria. In the real world, insurance underwriters are attempting to assess your personality—via your magazine and website subscriptions, the photos you post to social media, and more—to better determine how risky an investment you are. Some lenders have used personality algorithms to predict your future financial transactions. In human resources, hiring managers are using personality recognition systems to decide whether candidates make for a good cultural fit in their organization.

## 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—while invisible to everyday people—become more easily identifiable when scanned with beacons. Since 2018, researchers have published numerous papers about the technology. In addition, 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.

## 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. Users can control the Google Pixel phone without touching the phone's screen, by using motion sense and radar technology that detects micro-gestures. The technology stems from Project Soli, a miniature radar that understands human motion at different scales. Google's Advanced Technology and Projects group developed the technology, as well as Project Jacquard, the connected clothing system inside Levi's Commuter Trucker jackets. In early 2019 Google won U.S. Federal Communications Commission approval to run its Project Soli hand-tracking technology on commercial aircraft. We'll also start to see workplace applications that record body movement to predict when people will be most productive. It could also help security systems and teams predict when we might cause harm to others.

## Touch Recognition

Machine learning has been deployed to recognize objects solely by touch. Researchers developed a contact-based object recognition technique that recognizes different types of fruits, liquids, and other objects. Researchers at the Microsoft Research Lab, Dartmouth College, Wuhan University, and Southeast University developed the technology, called Capacitivo. It can identify objects of various shapes and sizes by using machine learning to sense changes in electrical fields, which relate to the size of an object and its composition.

## Bioacoustic Recognition

Sound continuously passes through space, even if we can't hear it. 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


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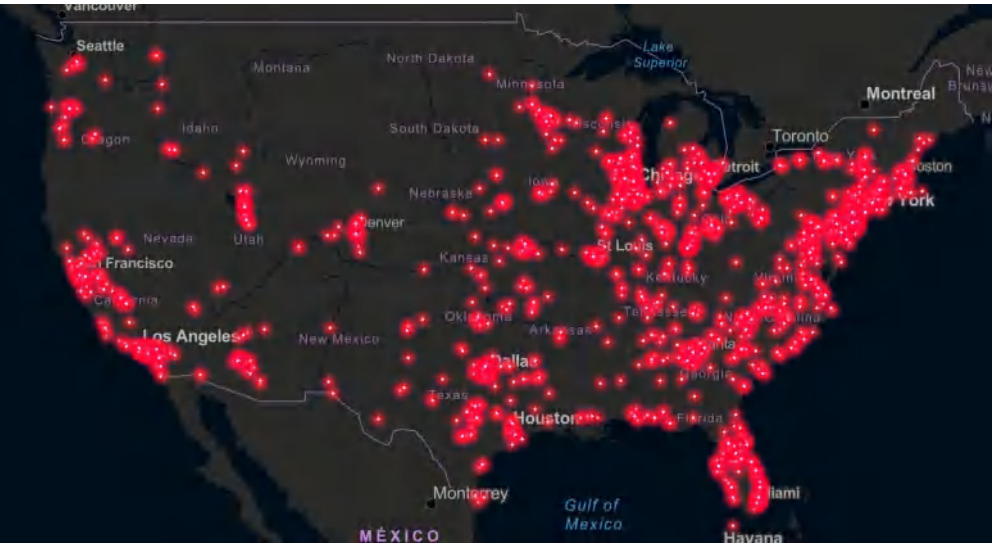
# Recognition Trends




**A map of Ring-police partnerships in the United States.**
Image credit: EFF.

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

We are continuously surrounded by radio waves, thanks to the millions of Wi-Fi routers around us. Unlike traditional computer vision systems, which typically require line-of-sight access to see, radio frequency can detect people, objects, and movements as far as the signal can broadcast. Even through walls. While you can't see, hear, or feel them, you're living in a field of 2.4 and 5 gigahertz radio signals. Anytime you move—take a sip of water, look out your window, wash your hair—you are distorting the waves. The Wi-Fi transmitter in your home or office is continually sending and receiving information, which it converts into radio waves. The signals aren't very strong, only filling up the space around you (and possibly spilling just outside to the street). It turns out that, with the right device, it's possible to watch us moving through the signals as they bounce off us and onto other objects. What this means in practice: Wi-Fi signals can be harnessed to recognize us and our movements through our walls. Researchers at the University of California, Santa Barbara, used ambient Wi-Fi signals and a smartphone to look for revealing pattern changes in signal strength. MIT's Computer Science and Artificial Intelligence Laboratory (CSAIL) and Massachusetts General Hospital developed a device that uses an advanced AI algorithm to analyze the radio signals around someone when they're sleeping. The system then translates those body movements into the stages of sleep: light, deep, or REM (rapid eye movement). Imagine a future in which your Wi-Fi router collects your physical movements, then calculates your health metrics, and automatically adjusts the devices and appliances in your house to help you live a better life. If you're snoring, for example, your pillow could automatically inflate or deflate to adjust the angle of your head and neck. Researchers at Northwest University in Xi'an, China, applied deep transfer learning to recognize subtle hand movements and interpret their meaning using Wi-Fi. Practical applications of the technology range from motion capture for video gaming to giving law enforcement and the military new ways to see through buildings.

## 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, which suggests that location can be pinpointed down to just a few feet. Kontakt.io's Bluetooth Card Beacon is a traditional security access card, but it also tracks employee movement throughout an office. Card beacon technology can au-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# Recognition Trends

tomatically recognize when an employee has left their desk and can automatically activate her computer's screen saver or customize meeting room temperatures. Tracking systems, combined with other AI systems, can assign people scores, too. For example, GAO Group developed a system that monitors location and predicts safety, develops better workflow optimization, and tracks employee productivity. SpotterEDU deployed its Bluetooth technology to 40 college campuses, including Indiana University and Columbia University. Proximity recognition technology might track students who are habitually late for class and don't visit the library enough—they could be labeled as "high risk" for dropping out.

## Two-Factor Biometric Authentication

Looking for unique biomarkers beneath our skin's surface is a clever way of identifying us—you can change your hairstyle or wear colored contacts, but it's really tricky to rewire your 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 developed a two-factor authentication method that first looks at skeleton topologies and then finger vein patterns.

## 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 corrects 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. Photographers could change perspective 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 to scenes, change shadows, reflections, and other atmospheric touches. Meanwhile, MIT's CSAIL and Google developed a technique to automatically retouch and enhance the pictures we take with our mobile phones.

## Biometric Camouflage

New fabrics and compounds help people fool recognition algorithms and, somewhat paradoxically, help them be seen more clearly. Fashion entrepreneur Saif Siddiqui created a scarf out of nano-spherical crystals that reflect light. When someone attempts to take a picture of a person wearing it, only the scarf will be visible in the resulting picture, while the wearer is camouflaged and blends into the background. In the U.S., Road Wise developed Safety Skin, a reflective lotion that makes your skin incredibly reflective. Ideal for nighttime runners or cyclists, the lotion can make them more visible to motorists. But the compound, which includes glass microspheres and plant-based emollients, also confuses recognition algorithms, effectively acting as digital camouflage for those who don't want to be seen. Meanwhile, Japanese company Real-f has developed super-realistic face masks made of plastic resin about 1 millimeter thick. The company can only produce 100 each year because it takes two weeks to make a mask. They can be made to look exactly like you to other humans while simultaneously confusing AI systems. Artist Jing-Cai Liu invented a wearable face projector that beams different images onto your face, subtly changing your appearance just enough to confuse the machines.

## Responsive Recognition Technology

Real-world conversation is full of nuance: We use words and emphasis in unique ways, we talk over 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 each other. 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. We also expect Alexa to someday interrupt and offer meaningful contributions to conversations.

## Affective Computing

Affective computing is an interdisciplinary field spanning computer science, psychology, neurobiology, and cognitive science, and it intersects directly with AI.



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# Recognition Trends

Recognition systems continually track us.

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. Scientists at the University of California, Berkeley, and Carnegie Mellon University used MRI imaging to determine which parts of the brain fired up during conversations, and mapped the subjects' emotional responses. Researchers at MIT are using electrodermal activity collected from our wearable computers—such as smartwatches or fitness trackers—and machine learning algorithms that respond to our emotions. But biological data from other sources can be useful, too: our skin, our faces, and our DNA. Analysts expect affective computing to become a $25 billion industry by 2023.

## Genetic Recognition

Late in 2019, popular U.K. grocery store chain Waitrose partnered with the DNA discovery platform DnaNudge. A pop-up service inside stores offered shoppers genetic testing, and an app that would "nudge" them, based on their DNA profile, to make healthier choices. The genetic recognition technology from DnaNudge required only a fast cheek swab. Customers could then use the DnaNudge app in Waitrose stores to scan barcodes and assess whether or not foods matched their genetic profile. 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 express 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 pervasiveness 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 10 million people have now paid the company to sequence their DNA, and 80% have consented to have their DNA used for drug research. 23andMe received $300 million to share its data with pharmaceutical company GlaxoSmithKline, and it also developed and sold a drug to Spanish pharmaceutical company Almirall designed to treat inflammatory diseases such as psoriasis.

## Universal Genetic Databases

The proliferation of consumer DNA testing services represents significant untapped opportunity in myriad industries and fields, including insurance, pharmaceuticals, and law enforcement. As a result, there is a new effort underway 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, Wharton School of Business professors 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


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# Recognition Trends

genetic profiles for every person living in or visiting a given country. Investigators found the Golden State Killer in 2018 using GEDmatch, the open-source genetic database that compares and matches DNA data files from different testing companies. It subsequently sparked renewed interest in developing universal genetic databases for government use. Of course, there are lots of ethical concerns. Under what circumstances could third parties pull and use genetic data housed in private databases? What jurisdiction should law enforcement have over our genetic data, even if we haven't committed a crime? China is building a universal database populated with the genetic information of its citizens; Saudi Arabia, Kuwait, and the U.K. are considering versions of their own.

**Most Americans would sign over their DNA data for $99.**

## Surveilling Vulnerable Communities

China deployed facial recognition software to identify Uighurs in Western China. Telecommunications giant Huawei reportedly worked with Megvii, one of the world's leading facial recognition startups, to build an AI-powered smart camera system that can identify the age, sex, and ethnicity of people in its line of sight. The system reportedly included a "Uighur alarm," to alert Chinese police. Uighers are a Muslim minority based in the northwest regions of China, near Tajikistan and Kyrgyzstan, and it is widely documented that millions of Uighurs have been forced into "reeducation centers," which reportedly involve sexual abuse and torture.

## Persistent Workplace and School Surveillance

In the U.S. and many other countries, schools and employers can legally monitor people, and they aren't always required to disclose what is being tracked. For years, China has deployed cameras and other technology in classrooms to monitor students' attentiveness. Microsoft mines chat, email, calendar, and meeting data to measure worker productivity within Microsoft itself. The company's sales team received personalized dashboards visualizing how they spend their time, and the system made recommendations to optimize their workflows. Bunch.ai monitors Slack channels to help managers understand their team dynamics and chemistry. Teramind's monitoring software captures real-time keystrokes, records video of employees' activity, and will send an alert to managers if an employee attempts to print a sensitive document. Humanyze uses Bluetooth-enabled badges to track workers throughout the day and then correlates that information with other data points drawn from email to find collaboration opportunities within teams.

## Efforts to Ban Facial Recognition

In New York, the Lockport City School District piloted its Aegis facial and object recognition system, built by SN Technologies, to quickly identify sex offenders. But some worried that it would be used to punish kids for minor violations. That led New York state to temporarily ban facial recognition and other biometric technology in schools until July 1, 2022—or until officials deem the systems as safe, secure, and preserving student privacy. Last year, the Los Angeles Police Department banned the use of third-party facial recognition systems, including Clearview AI. Paradoxically, the LAPD did request Ring footage of Black Lives Matter protests from networked home surveillance in the summer of 2020.

## 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. A few dozen labeled training images can determine, for instance, the presence of onion skin among peeled onions and hulls on sunflower seeds.

## Wrongful Recognition

Last year, police falsely arrested a New Jersey man because of an incorrect facial recognition match. Nijeer Parks says he spent 10 days in jail—including a week in functional solitary confinement—after the recognition system identified him as a shoplifter. Two more incidents, both in the Detroit area and both using facial recognition technology, led to the wrongful arrest of the men. In all three cases, 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.



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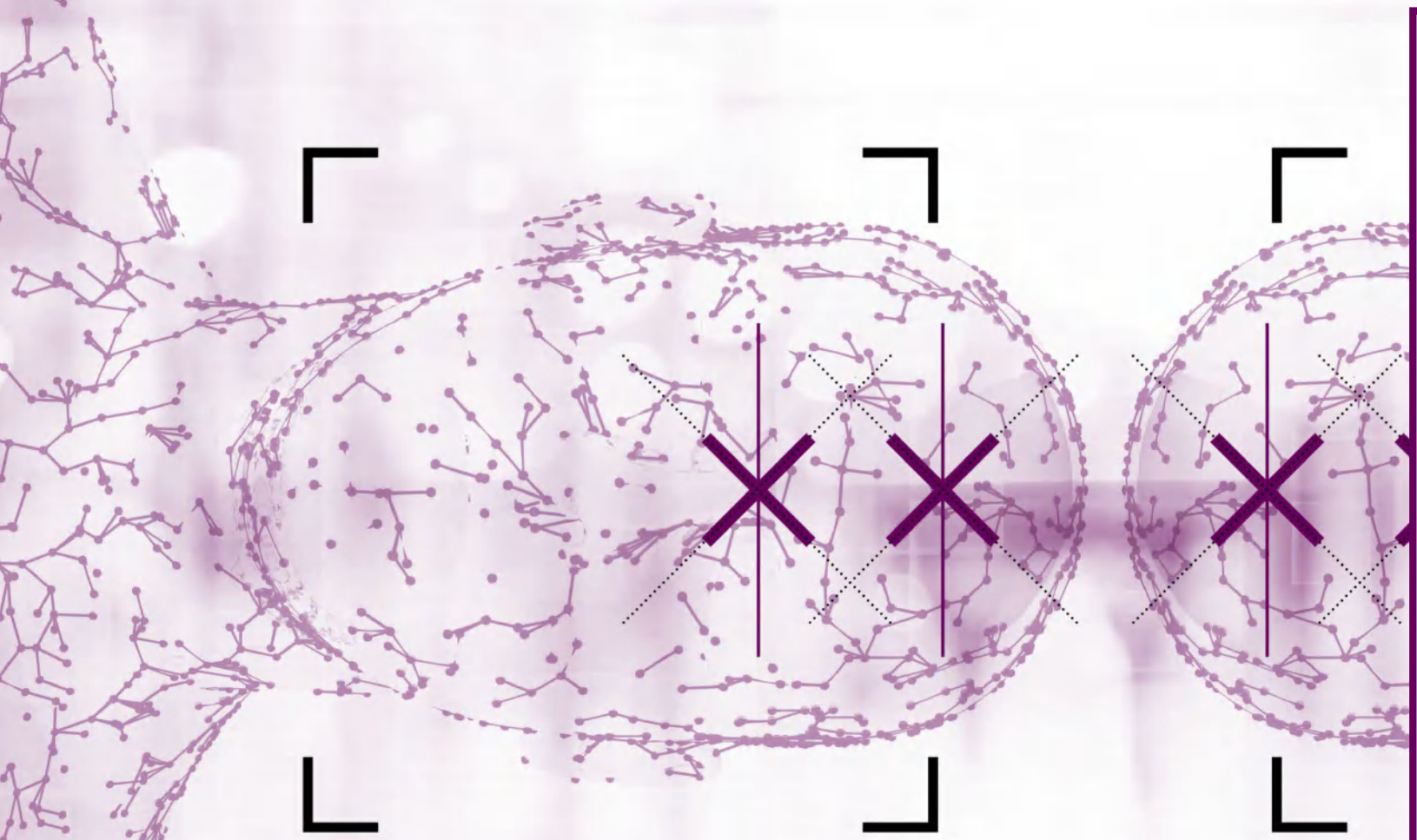

## Your Body Is a Dataland

### Mid-future catastrophic scenario

During the pandemic, we transitioned to telemedicine and remote patient monitoring systems, which relied on AI. At first, it was a more equitable way to distribute healthcare benefits and to manage the shortage of providers. Automation led to efficiencies and cost savings. A decade later, there are no more in-person doctor exams. Instead, the data from your smart devices are continuously mined and analyzed. An AI agent anticipates your health problems in advance and adjusts your permissions accordingly. If you want to see a doctor, you need a referral from an AI agent—but you won't get one unless you comply with your optimization plan. Your wristband knows if you're stressed, and your smart toilet detects that you've eaten too much sugar. Your smart garbage can sees that you've thrown out Twinkie wrappers. Sweets aren't on your health plan, so the garbage can sends a message to your AI agent. It's another negative mark on your digital health report card. You finally hack your garbage scanner, but since it's connected to city services, you're now denied garbage pickup. Your body isn't a wonderland. It's a container for data.

# Scenarios



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# Scoring

3RD YEAR ON THE LIST

# Scoring

McDonald's deploys scoring technologies to customize drive-through menu screens.

## KEY INSIGHT

**For our automated systems to work, they need both our data and a framework for making decisions. Everyone alive today is being scored.**

## EXAMPLES

In the U.S., we have a credit reporting system that measures our creditworthiness. Banks, financial institutions, and others use that score to determine the likelihood that we might default on a loan or a mortgage. Financial credit scoring is tightly regulated and 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

Recent advancements in data mining and artificial intelligence promise new opportunities for business intelligence and law enforcement. There are risks, too: China is selling its government-funded scoring tools to authoritarian regimes elsewhere in the world. We anticipate that in the coming year, regulators will take a deeper interest in scoring, even as the pandemic provides new, practical use cases for the wide deployment of scoring algorithms.

## EMERGING PLAYERS

- AI Now Institute
- Cognitive Systems
- Clarifai
- Dahua Technology
- Density
- The Greenlining Institute
- Kount
- Lieber Institute for Brain Development (and the University of North Carolina School of Medicine
- MaxMind
- The Retail Equation
- Riskified



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# Scoring Trends

Everyone alive today is being scored.

There's an old Chinese adage that says, "People are doing things, and the sky is watching." But it holds true for the West, too. Increasingly, everything we do is being watched and recorded. Algorithms assign us scores all the time, by governments in some countries and by the commercial sector in others.

## Biometric Scoring

Quantifying and analyzing our biometric data can reveal patterns in our activities—and as a result, can reveal 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 C's and V's 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. We also don't realize that in the near future, they 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 typing a few sentences. The downside: If your behavior is observable, at some point it will become repeatable, too.

## 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 now being used in over-the-counter genome sequencing kits (such as 23andMe) and in wide academic studies. For example, Lieber Institute for Brain Development and University of North Carolina School of Medicine scientists are building genetic scores for schizophrenia-related genes in the placenta.


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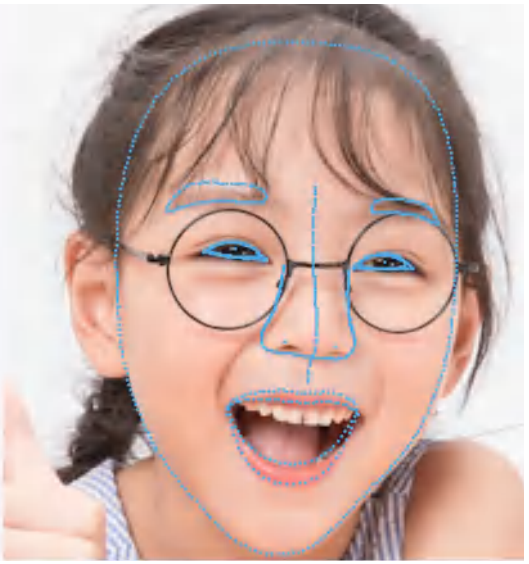
# Scoring Trends



Megvii's Face++ can accurately locate facial features and facial contours using 1,000 unique factors. The system works in milliseconds.

## Anonymous By Design

In the wake of privacy concerns, some developers are building products that recognize and quantify us—but without revealing our individual identities. Anonymizing data after the fact requires exceptional data governance, which is difficult for some companies to achieve. For example, Canada-based Cognitive Systems uses Wi-Fi signal disruptions to determine movements, such as when someone falls. The software registers an event without divulging who fell, their prior actions, or any other personally identifiable information. Georgia-based Density created a people-counting sensor for buildings that uses depth perception to count people using only their height.

## Scoring Agencies On the Rise

Hundreds of companies now score customers. Some, such as Kount and Riskified, focus on niche areas like fraud detection, while Kustomer scores people more broadly to determine purchasing power and their general frame of mind. Retail Equation's algorithms tell Best Buy and Sephora whether to accept or reject the online purchase of a product by a specific customer. McDonald's acquired Dynamic Yield to predict and customize menus based on consumer scoring profiles. Zeta Global scores people based on how much money they are likely to spend, while MaxMind scores customers based on their location in the real world. Collectively, 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.

## 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. Researchers at the University of Colorado Boulder showed how scoring tools—including facial analysis systems by Clarifai, Amazon's Rekognition system, IBM Watson, Megvii's Face++, and Microsoft—habitually misidentified non-cisgender people. Another study by MIT Media Lab found that 33% of the time, Rekognition misidentified women of color as men. Even so, companies and government agencies continue to score vulnerable communities. Law enforcement, immigration officials, banks, universities, and even religious institutions now use scoring systems.

## 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. In February 2018, Amazon acquired the video-equipped smart doorbell company Ring, and three months later it launched Neighbors, a crime-reporting social network that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# Scoring Trends

encourages Ring users to upload videos from their security cameras and doorbells for others to see. Now, more than 1,300 law enforcement agencies in the U.S. use data from Ring—a 225% increase from 2019.

## 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. For example, The Greenlining Institute, aCalifornia-based nonprofit working for racial and economic justice, examines how poorly designed algorithmic scoring systems threaten to amplify systemic racism, gender discrimination, and prejudices against people with lower incomes. It reviewed an algorithm that Stanford Medicine used to determine the order in which Americans should receive COVID-19 vaccinations, and it prioritized older doctors who weren't regularly seeing patients over younger, front-line resident physicians. (Stanford stopped using the algorithm and instead intervened to vaccinate those at highest daily risk of infection.) Despite agreement that we have a bias problem, the tech industry still has no plan for how to address and solve for bias in recognition systems that continuously score all of us. The algorithmic bias problem will likely get worse, especially as more law enforcement agencies and the justice system adopt recognition technologies.

## 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. This year, California could implement a new standard that requires businesses to test any automated decision systems for bias before deployment. If the bill passes, it would be the first law of its kind in the U.S. The European Union's GDPR regulations restrict what kinds of personal data can be collected and under what circumstances, but even local authorities enforce the law differently. 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 designed to enhance our digital experience instead track us without explicitly showing how or why. For example, in trying to distinguish between humans and bots online, some verification systems use technology that's not easily visible. CAPTCHAs, which stand for "completely automated public Turing tests to tell computers and humans apart," are common challenge-response tests. To protect against automated account creation, they ask users to complete a task that's easy for humans, but challenging for computers—such as clicking on pictures of a traffic light. In 2009, Google acquired reCAPTCHA, a popular version of CAPTCHA technology. Its latest iteration is invisible. Rather than asking consumers to click a box saying "I'm not a robot" or select which pictures show traffic lights or bananas, this latest version invisibly tracks how someone navigates through a website and assigns them a risk score based on that behavior. While it may be far less annoying than clicking through the old process, this system looks for other details, such as whether someone already has a Google cookie in their browser and whether they are logged into a Google account. Over time, the system learns the patterns of real people—but it also means that Google could gain access to every single page you access.

## Algorithmic Determinism

Data is being mined, refined, and productized in order to sort, tag, and catalog people. Why? To make it easier for systems to make decisions for, on behalf of, and about them. In this new age of algorithmic determinism, AI systems assign scores in the absence of context or special circumstances. In the digital realm, statistical learning techniques are used to create digital identities for individual users, including their preferences, use patterns, and the structure of their social graphs, among other factors. AI systems assign scores based on limited historical data, and the result is a caricature of what machines think we are, rather than a reflection of our true selves. AI systems continue to mine and crunch data, again and again, until a predefined goal is achieved.


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# Scoring Trends

Autonomous security checks in China match passenger faces with ID databases.

## Scoring in China

By now, you are likely familiar with China's Social Credit System, a vast ranking system that this year will see a national rollout. First announced in 2014, it promised to make good on the government's stance that "keeping trust is glorious and breaking trust is disgraceful." The system will take some time to become fully operational nationwide, but already it's granting and restricting permissions for Chinese citizens algorithmically. People are awarded or deducted points for a variety of activities, such as whether they pay bills on time, spread news contrary to the government's viewpoints, or spend too much time playing video games.

### Scoring Companies

A longstanding goal of China's Social Credit System is to create what the Communist Party of China (CCP) calls a "fair, transparent, and predictable" business environment. To accomplish that goal, China's ambitious Corporate Social Credit System (CSCS) comprises a nationwide data-gathering effort intended to regulate corporate behavior. The CSCS poses a new threat to businesses operating in China; businesses could be subjected to arbitrary rule enforcement or new regulations regarding IP or tech transfer. The CSCS includes a plan for centralizing data from domestic and foreign companies inside a government system, allowing the CCP to monitor the activities of all entities operating in China. Chinese companies and trade associations are required to contribute data about their foreign partners and to enforce blacklists.

### Scoring Uighurs

In late 2019, the 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 Uighur community lives. The International Consortium of Investigative Journalists published a detailed report showing the scope and ambition of Beijing's scoring system, which awards points and punishments for inmates in the camps. China argues its "re-education camps" and scoring system were built to combat terrorists and radical religious extremism.


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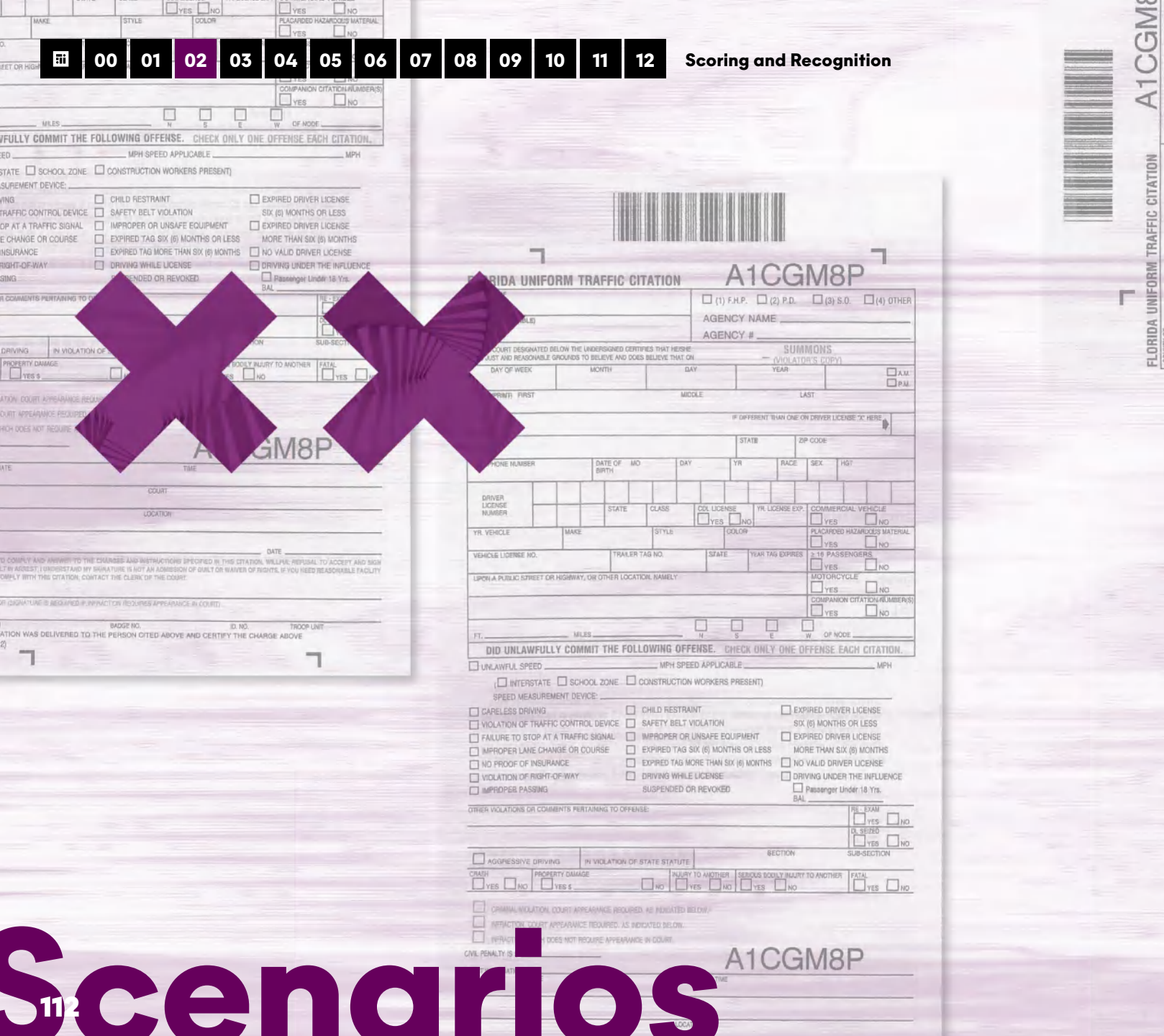


## Micro-Policing

### Mid-future pessimistic scenario

Driverless cars put a dent in traffic tickets, a key source of revenue for police budgets. This unintentional defunding leaves law enforcement searching for new sources of income. Scoring and recognition programs provide an answer: micro-policing, which involves tracking down and charging people for minor crimes and infractions using recognition technology such as biometrics, proximity sensors, spatial internet, and more. Littering, jaywalking, and even "borrowing" your neighbor's Wi-Fi come with hefty fines. Obscure, outdated laws that haven't been applied in ages are suddenly revived and enforced. This practice of micro-policing may be a boon for police departments, but the constant fear of being fined for barely perceptible infractions has citizens longing for the days of good old parking tickets.



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# Application

## STRATEGY

Strategy officers should view scoring as an opportunity and a risk. 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 the company? How does scoring fit into the company's longer-term growth ambitions?

## INNOVATION

In what ways could algorithmic scoring itself be improved? For companies that engage in scoring, there is 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 the outcomes that are generated. 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. As new research is pursued, transparency should be prioritized. 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.

## RISK

Scoring presents tremendous opportunities to help businesses understand their customers better, which is why in 2021, every organization must develop a data governance strategy and ethics policy. For those who work in risk and compliance, this will be the start of a newly complicated landscape. Organizations will need to hire compliance specialists who understand the complexities of using scoring systems in general, and as they relate to worker or customer safety in the wake of COVID-19. For those in the public sector, massive-scale scoring impacts every facet of our daily lives, and it will soon influence geoeconomic relationships around the world.



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# 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 about recognition and scoring:

1

What new insights require a deeper understanding?

Where must we take action in the next quarter or year?

These include issues related to proposed or new regulations, changes in technology, and shifts in consumer sentiment (domestic and international).

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

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

Do our employees understand this position?

Do our customers?



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Volume 3 of 12

14th Annual Edition

# 2021 Tech Trends Report

Strategic trends that will influence business, government, education, media and society in the coming year.

- New Realities
- Synthetic Media
- News
- Information

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# New Realities, Synthetic Media, News & Information Summary

- As current forms of digitally mediated reality evolve and new forms emerge, they are poised to merge along a virtuality-reality spectrum.
- Diminished reality, or DR, is a form of augmented reality focused on suppressing existing elements of our physical environment, rather than introducing new digital elements to it. DR represents a unique and extensive range of AR applications.
- The shift from hands-on to heads-up is upon us, marked by the gradual transition from smartphones to smart eyewear.
- With advancements in spatial internet, and the impending spread of 5G and smart eyewear, the prospect of a metaverse—a persistent, shared, digitally mediated realm that layers into the physical world—is coming into focus.
- Smart eyewear will rely in part on advanced voice technology, so expect investment and advancements in natural language processing and generation, and emotive recognition.
- The combined augmented and virtual reality market is estimated to be valued in the hundreds of billions of dollars within the next decade.
- Synthetic media will become an integral part of our future XR experiences.
- In the wrong hands, synthetic media can be a powerful and dangerous tool in spreading misinformation and disinformation.
- As margins continue to shrink in news media, industry consolidation continues, at the expense of journalistic integrity.
- News outlets are encountering competition well beyond their industry as the subscription economy matures and an ever-growing list of companies vie for the attention, time, and money of an overstimulated audience.


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> I do think that a significant portion of the population of developed countries, and eventually all countries, will have AR experiences every day, almost like eating three meals a day. It will become that much a part of you.
>
> — Apple CEO Tim Cook

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# New Realities

# Keeping Track of New Realities

Technology now blends the physical and virtual worlds.

As a constellation of technologies including smart eyewear, game engines, natural language processing and generation, volumetric video, and haptics continues to evolve, it is critical that we draw distinctions between the various digitally mediated realities that span the reality-virtuality spectrum. With AR, VR, MR, XR, and DR—and more R's inevitably on the way—reviewing their definitions and differences is the first step toward better understanding the future of the field.

## 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 sometimes overlaps with varying definitions of the virtuality-reality spectrum, spatial computing, or Web 3.0, and the so-called metaverse.

## 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 subset of AR—that does not mean, however, that all AR is DR.



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1ST YEAR ON THE LIST

# Diminished Reality

Diminished reality has the power to remove objects from view, seamlessly filling in backgrounds to mask the objects' absence.

## KEY INSIGHT

**Diminished reality (DR) is the field of AR that focuses on virtually masking, reducing, or suppressing features of one's environment. As smart glasses proliferate and AR becomes commonplace over the next decade, DR presents an opportunity to virtually shape our reality rather than simply build on top of it.**

## 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, it will allow users to target specific stimuli to suppress, isolating a specific speaker's words and appearance in a crowded room, or removing all advertising from view during a walk through the city center. But there are also therapeutic applications for those with unique sensitivities, such as for those suffering from PTSD. 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
- Google's ARCore
- Vuforia Engine



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4TH YEAR ON THE LIST

# Smart Eyewear and Head-Mounted Displays

The first generation of smart eyewear resembles traditional glasses, but future iterations will incorporate the technology into something akin to a contact lens.

## KEY INSIGHT

**Smart eyewear and head-mounted displays (HMDs) are already on the market; as the devices spread, generating more real-world data with which to update and fine-tune their hardware and operating systems, they are strongly positioned to replace smartphones as the primary personal device.**

## EXAMPLES

The transition from hands-on to heads-up mobile computing has begun, with everyday smart eyewear trickling into the consumer market. Amazon's Echo Frames, which were quietly made available to the public at the end of 2020, prove that smart glasses can have "dumb" lenses—the tech in these frames is purely auditory (they have an on-board Alexa voice assistant), using bone conduction technology rather than in-ear components. The audio-first approach is a clever way to ease smart eyewear into the market, avoiding the privacy concerns surrounding video-enabled products like the conspicuous—and widely criticized—original Google Glass. It also gives manufacturers more time to engineer the complex smart lens systems that will eventually support XR applications. Watch for sleeker but simpler smart eyewear devices and bulkier but more powerful HMDs like Facebook's Oculus Quest and Microsoft's HoloLens to inch closer to one another in terms of capabilities and form factor.

## DISRUPTIVE IMPACT

Smart eyewear is expected to upend industries and interfaces designed for the smartphone by offering a more versatile hands-free alternative to the trusted mobile device. HMDs, on the other hand, have already begun to reshape enterprise solutions, from the field to the factory floor. Current smart eyewear, often designed to resemble recognizable traditional eyeglasses with simple but useful connected features, is meant to seamlessly blend into our everyday lives and facilitate daily activities. HMDs, which offer more robust functionality 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. As smart eyewear adds more advanced features, and HMDs become more lightweight and comfortable, the two closely related technologies may begin to converge.

## EMERGING PLAYERS

- Amazon's Echo Frames
- Apple's forthcoming smart eyewear product
- Epson Moverio
- Facebook's Oculus Quest 2
- Microsoft's HoloLens 2
- Solos
- Snap Spectacles 3
- Vue
- Vuzix Blade



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4TH YEAR ON THE LIST

# AR for the Enterprise

Microsoft's HoloLens 2 was designed specifically with business solutions in mind.

## 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, while VR takes longer to mature.**

## EXAMPLES

Microsoft's HoloLens 2 head-mounted display 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, with thermal imaging and night vision among its many advanced capabilities. Smart eyewear and HMD maker Nreal has announced an Android-compatible "all in one" enterprise headset that looks more like a helmet than a pair of glasses, with on-board edge computing capabilities. The uses of these business-focused 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

- CAE
- GIGXR
- Hevolus
- Kognitiv Spark
- Medivis
- Nreal
- PTC
- Spatial
- Trimble



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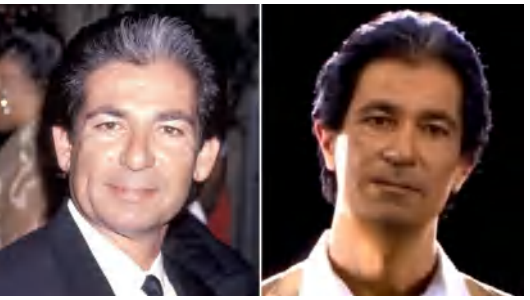
7TH YEAR ON THE LIST

# Holograms



**Prominent attorney Robert Kardashian (left), who passed away in 2003, was re-created in holographic form (right) by production house Kaleida in 2020 as a birthday gift for his daughter Kim.**

Image Credit: GETTY IMAGES/@KIMKARDASHIAN

## KEY INSIGHT

**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.**

## EXAMPLES

In December 2020, Netflix launched an AR hologram tool ahead of releasing the George Clooney movie "The Midnight Sky." It let people record and upload a short video message and see it transformed into AR holograms. Blank XR is developing a concert platform that would allow fans to engage with musicians' holograms via a mixed-reality application. Los Angeles startup Portl launched phone booth-sized boxes that can project a real-time, full-size holographic likeness of a person or character. Holograms have been key to successful concert tours featuring bygone stars like Roy Orbison and Frank Zappa, and will soon allow production companies to draw popular synthetic media influencers like Lil Miquela and artists like Japanese act Hatsune Miku out of our screens and into our spatial environment.

## DISRUPTIVE IMPACT

The accurate digital reproduction of faces, bodies, and other complex structures in dynamic 3D form is critical to the evolution of augmented and virtual reality. As smart eyewear edges out the smartphone as our primary personal device, holograms, variously combined with deepfake technology and synthetic media, may soon inhabit our everyday environments. They'll represent a range of artificially generated characters, celebrity stand-ins, brand spokespeople, historical figures, and lost loved ones. In the medical field, holographic mapping can provide doctors with a 360-degree view of a patient's internal organs, vessels, bones, and tissue, which can assist with diagnostics and surgeries, with multiple apps already approved by the U.S. Food and Drug Administration. As it evolves, this technology could be used in remote workplace training and collaboration. Expect to hear more about holograms as resolution, volumetrics, and depth of field improve, and as 5G fuels the level of high-bandwidth instantaneous data transfer needed for lifelike holographic streaming.

## EMERGING PLAYERS

- Blank XR
- Netflix
- Portl
- Kaleida
- Eyellusion
- Base Hologram Productions
- Hologram USA
- EchoPixel
- OpenSight
- Crypton Future Media



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## Eco-Sight

**Near-future optimistic scenario**

There's more to reality than what meets the human eye. As we extend technology past the limits of our senses, we create filters that allow us to see through the eyes of other species. Earth looks like a different planet. To the mantis shrimp, the ocean is an aurora borealis of previously unimagined colors. Birds look brighter and more opulent when we finally see them through their own eyes. Mushrooms littered across the forest floor are revealed as the various fruiting bodies of one unified underground organism. These eco-sense experiences make their way into school curricula, corporate retreats, therapeutic programs, environmental policymaking, and the art world. The more time we spend using the filters to augment our senses, the more empathy we develop for the natural world, seeing nature as it sees itself. These experiences make us more life-centric, motivating us to nurture and protect our planet.

# Scenarios



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1ST YEAR ON THE LIST

# Spatial Displays

Sony's Spatial Reality Display follows eye movement down to the millisecond.

## KEY INSIGHT

**Holographic displays allow content creators to see their digital designs in physical space.**

## EXAMPLES

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 hyper-realistic, 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 last fall with a dedicated software development kit supporting Unity and Unreal Engine 4.

## DISRUPTIVE IMPACT

For now, this technology is 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. Doctors will show their patients what's going on inside their bodies, and history teachers will take students on tours of ancient ruins.

## EMERGING PLAYERS

- Sony
- Intel
- Unity
- Unreal Engine



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# New Realities Trends

Australia-based Imagine Room operates the country's first Mixed Reality Capture Studio.

## 360° Video

360-degree video is created with a special camera rig designed to capture omni-directional footage. Once the video is rendered, viewers can rotate their point of view using a mouse, touch-screen, or motion-control gesture to explore the recorded scene. The format offers a more immersive and active viewing experience for entertainment, documentary, and news than traditional video, but one that can still be viewed through standard mediums like laptop and mobile device screens. It is a relatively simple and low-cost alternative to the total immersion of more advanced forms of virtual reality.

## Volumetric Video

A pivotal technology for developing XR experiences, 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 360-degree video allows viewers to rotate their perspective and view the full scope of their surroundings from a fixed point, volumetric video 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.

## 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.

## The Metaverse

A term originally coined by Neal Stephenson in his iconic 1992 sci-fi novel "Snow Crash," the metaverse refers to an all-encompassing shared virtual realm. While definitions vary, and some have strayed from the novel's depiction of the concept, today the metaverse is often described as persistent—meaning its collective network of 3D virtual spaces cannot be turned on or off, but exists continuously—and shared—meaning various users can access it freely and interact within it. By most definitions, the metaverse encompasses all AR, virtual realms, and the internet. While the concept can be difficult to grasp at the moment, it is likely to come into clearer focus as AR and VR platforms proliferate, and virtuality becomes a regular, if not constant, part of our everyday lives.


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# Expert Insight

## The Future of Live Entertainment

**Corey Johnson**

CEO/Partner,
ProductionClub

Live music and entertainment will never be the same. Where less than two years ago live-streaming and virtual events were the odd stepchild of the live events industry, this segment not only became relevant but entirely supplanted the traditional live event and entertainment industries in 2020. The pandemic triggered a rapid shift of focus, the creation of new business paradigms, and a series of innovations that will revolutionize events and create an entirely new type of live experience in the future. This new type of hybrid entertainment will combine the best of in-person live events, broadcast, interactive digital media, and real-time game environments.

### Technology in events and live entertainment

For the past decade, digital technologies have had a growing influence on the live music and entertainment industries. Technologies such as XR (extended reality), AR (augmented reality), and VR (virtual reality) have been developed and touted as revolutionary. Low-cost, low-power LEDs have transformed lighting technology and the availability of higher-quality, higher-resolution displays have cemented the role of video and visuals as an essential part of the live experience. Further, real-time game engines such as Unreal and Unity have gone from the realm of experimentation and innovation into founda-

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> So what will events of the future look like? No one knows exactly, but the virtual event genie is not going back in the bottle.

tional building blocks and tools for creating the live environment.

However, until recently the applications of these new technologies has been primarily in support of the in-person, physical live event experience. Technology has been used to create video elements, add spectacle and visual intrigue, or more deeply embed brands and advertisers into the event. All of this changed in 2020. COVID-19 not only made in-person live events challenging, but impossible to be done safely and at any viable economic scale. As such, live streaming and virtual event platforms went from the periphery to the center of the action.

At the start of 2020, live-streaming and virtual event platforms were more-or-less irrelevant as far as the public was concerned, but by mid-year they were the only way to gather and had entirely replaced live concerts, conferences, and entertainment worldwide. Twitch, for example, was regarded as a fringe streaming platform where gamers could gather and watch each other play. Discord was the same, existing as a communication tool for small communities. Even the top enterprise players such as Zoom or Skype were primarily viewed as business tools, certainly not as technology platforms replacing any and all group gathering and socialization at global scale.

Now in 2021, the industry still finds itself contending with significant uncertainty. Festivals such as Coachella have been canceled for the second year in a row, industry giant Live Nation's revenue dropped 95%, and the timeline and comeback of concerts is unknown and will be dictated by the success (or failure) of vaccines.

So what will events of the future look like? No one knows exactly, but the virtual event genie is not going back in the bottle. What was once an after-thought is now the focus of an entire industry. This year, 2021, will be full of innovation. It will include new companies and platforms that have not previously existed, next-generation XR performances and awards shows such as MTV's VMA Awards, and new initiatives from incumbents, such as Sony, which is building an in-house studio dedicated solely to creating these immersive at-home experiences. With Travis Scott's Fortnite performance live-streamed to more than 12 million simultaneous users and an entire generation of youth spending their social time in Roblox—which is valued at $30 billion with 150 million monthly active users—the forthcoming shifts in the industry look to be tectonic in scale.


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> It is clear that technology's impact on live events and entertainment is still in a nascent phase. There is much more to come.

## Looking forward

At Production Club, we believe that the future is not about whether events will be physical or virtual. It is highly likely that the innovation will occur simultaneously in both physical and virtual mediums.

We are calling these hybrids "Collective Experiences." This new type of event will happen all at once in physical venues, on web-based interactive live-streams, and on virtual avatar-based game platforms. These events will not be constrained by physical location or time in the same way that events were prior to 2020. Technology will continue to accelerate and empower this transformation with a far greater emphasis on the virtual medium, as audiences wake up to its possibilities, efficiency, and offerings. Further, as gaming and tech companies explore ideas like the metaverse as depicted in science fiction like "Snow Crash" and "Ready Player One," it is clear that technology's impact on live events and entertainment is still in a nascent phase. There is much more to come.

Covid has reinforced and solidified the fact that humans have a fundamental and irreplaceable desire to gather, communicate, socialize, and be entertained in groups large and small. In the coming years, technology must be developed to support, enhance, and accelerate collective experiences by offering more quality, diversity, and accessible live entertainment for all. Ultimately it's not about the technology itself but how it is utilized to bring us together that matters.

**

*Corey Johnson leads Production Club's overall direction and focus, working across the creative and production spectra.*



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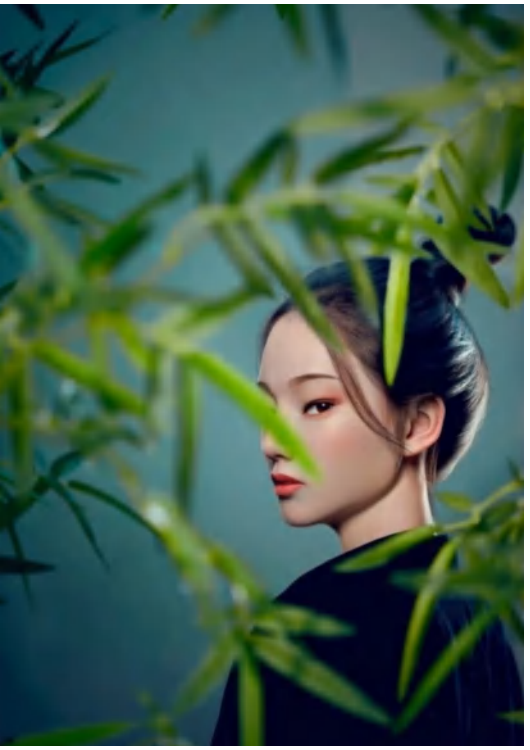
# Synthetic Media & Content

2ND YEAR ON THE LIST

# Synthetic Media and Content



Chinese virtual influencer Ling debuted in May 2020.

## 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.**

## 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, voice skins, unique gestures, photos, and interactive bots are all part of the ecosystem. Synthetic media can be used for practical reasons, such as generating characters in animated movies or acting as a stand-in for live action movies. Synthetic media can automate dubbing in foreign languages on video chats and fill in the blanks when video call frames are dropped because of low bandwidth issues. Imagine an entirely new genre of soap opera, where AI systems learn from your digital behavior, biometrics, and personal data, and use details from your personal life for the storylines of synthetic characters. In an ultimate expression of a "reality show," synthetic characters would play to an audience of exactly one: you.

## DISRUPTIVE IMPACT

Watch for synthetic media to appear more frequently in 2021, representing new opportunities and risks for businesses, and reshaping the entertainment, service, and communications landscape.

## EMERGING PLAYERS

- Samsung Next
- Loudly
- Endel
- Replica Studios
- Lovo
- Modulate
- Rephrase.ai
- Synthesia
- Alethea.ai
- Carv3d
- Animatico
- Narrativa
- DeepNatural
- Baidu Research



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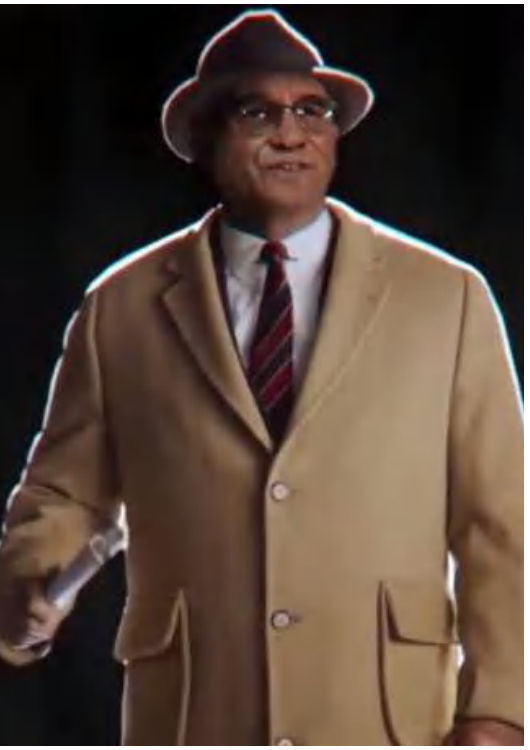
# Synthetic Media Technologies



The 2021 Super Bowl aired a commercial featuring a synthesized Vince Lombardi.

## 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. One 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 synchronized correctly.

## 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, Voicemod, Resemble Ai, and DeepZen 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. If you loved "Daria" as a kid, you might hear Daria Morgendorffer's voice (or Jane Lane's) during a car commercial, while your spouse might instead hear Phil and Lil's mom from "Rugrats." We should remember that in this era of misinformation, synthetic voices might also be used to trick unwitting consumers.

## Deep Behaviors and Predictive Machine Vision

Researchers at MIT's Computer Science and Artificial Intelligence Laboratory (CSAIL) trained computers to not only recognize what's in a video but to predict what humans will do next. Trained on YouTube videos and TV shows such as "The Office" and "Desperate Housewives," a computer system can now predict whether two people are likely to hug, kiss, shake hands, or slap a high five. This research will someday enable robots to more easily navigate human environments—and to interact with humans by taking cues from our body language. It could also be used in retail environments, while we're operating machinery or while we're in classrooms learning.

## Generative Algorithms for Voice, Sound, and Video

A team at University of California, Berkeley, created software that can transfer the movements of one person in a video to someone in another video automatically using a generative adversarial network. For some time, we've been training computers to watch videos and predict corresponding sounds in our physical world. For example, researchers at MIT's CSAIL experimented to learn whether a computer could accurately predict what sound is generated when a wooden drumstick taps a couch, a pile of leaves, or a glass windowpane. The focus of this research is to help systems understand how objects interact with each other in the physical realm.

## Mapped Synthetic Environments

Companies are now mapping the real world to generate synthetic digital twins. Amazon has been studying Snohomish County in Washington, building realistic simulations of the region's roads, buildings, and traffic. Its maps are reported to be accurate down to the centimeter, precisely tracking subtle gradients in pavement and noting unique markings on sidewalks. Amazon fused maps and 3D data to build synthetic versions of the county to test delivery drones. These kinds of virtual environments will be necessary as the company moves drones from research labs into the mainstream. Amazon tested its Scout delivery robot in the real world, having trained it in the synthetic environment.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# Synthetic Media and Society

Frank is an artificial person from Samsung.

## Live Portraits

In a new application of synthetic media, Israeli startup D-ID used its face recognition technology to generate live portraits from old photos. Members of MyHeritage, a genealogy platform, could upload old family photos or animate those already in the platform's database. The result: live portraits, reminiscent of "Harry Potter." The technology maps a digital picture to an AI system that renders smiling, blinking, and head movements in a short video.

## Synth-pop Makes a Comeback

Synthetic media will give rise to an entirely new kind of celebrity in the 21st century: synthetic pop stars. It also affords a host of opportunities to make and save money. Already there are a number of synthetic pop stars with very large fan bases. Lil Miquela is a sort of Beyonce of synthetic stars, with 3 million followers on Instagram as of the start of this year. She is a model for brands like Prada and Calvin Klein, a musician with popular tracks on Spotify, and a paid brand ambassador for enormous, global companies like Samsung. And she has friends: Bermuda, a rule-breaking bad girl model/influencer and Blawko, a Los Angeles–based guy who likes fast cars and Absolut vodka, and is never without his trademark face scarf covering his nose and mouth. In many ways, these stars are the antidote to teen stars like Lindsay Lohan and Shia LeBeouf who, for one reason or another, stray from their carefully crafted public images and cause headaches for their agents, managers, and the brands or projects they represent. Synthetic stars don't sleep. They don't eat. They never get tired, even if they're pushed 24 hours a day. They don't drink alcohol or use drugs, would never say anything off-message, and their mug shots would never go viral. (Unless it was planned, of course. Over the summer, Bermuda posted her own mugshot on Instagram to "get ahead" of the press.) While Bermuda and Blawko aren't programmable yet, China's AI news anchors are. China's state news agency Xinhua employs AI news anchors Xin Xiaomeng, Qui Hao, and Xin Xiaohao, who appear in videos and also write stories for the agency.

## Simulating Human Experiences

What if you could interact with a simulated person to learn from them or practice management techniques? Would you invite a synth to a dinner party? Samsung's Technology and Advanced Research Labs (STAR Labs) thinks the answer is yes. It developed Neon, "a computationally created virtual being that looks and behaves like a real human, with the ability to show emotions and intelligence." Neons aren't intended as a stand-in for the internet. They were built to hang out with you. U.S.-based startup Talespin built synths in virtual reality to teach people "soft" management skills, including how to encourage team members or how to fire someone with empathy and compassion. Canadian startup TwentyBN built a synthetic sales associate to cheerfully interact with customers—and convince them to spend more money.

## Synthetic Voice Fraud

Synthesized media has a known problem area: It can be used by malicious actors to mislead people, to trick voice authentication systems, and to create forged audio recordings. Voice fraud costs U.S. businesses with call centers $14 billion last year alone, according to a study by call center software maker Pindrop. Google has been working on a synthetic speech dataset as part of the ASVspoof Challenge, which is an open-source, global initiative designed to help develop countermeasures to fight spoofed speech. Researchers hope that the challenge will lead to more secure synthetic voice content.


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# Synthetic Media and Society

## Synthetic Sex Tapes

Natalie Portman, Emma Watson, Taylor Swift, and Daisy Ridley—smart, talented artists—began "appearing" in adult videos in late 2018. Convincing short clips were made using deepfake techniques and soon went viral on Reddit. Not too long after, another Reddit user published a mobile application allowing anyone to make their own porn deepfakes. This poses a particular problem for public figures, because right now there isn't an easy way for the average person to tell what's real and what's fake. Photos and videos can spread through social networks and online without much protection for those victimized. In the absence of digital tools to spot fakes, we're left relying on critical thinking and common sense.

## Synthetic Property Rights and Legal Protections

The video game "Call of Duty: Modern Warfare" was designed with brutal realism. Players enter lifelike combat situations and must decide whether to shoot synthetic civilians. Where do we draw the lines between disclosure and pure fantasy? Parody for laughs and deepfakes for harm? What happens when synthetic content seems so real that the psychological implications are intense and profound? What if someone generates synthetic environments that mirror real-world situations and real people? No existing laws or regulations govern synthetic content, although some people suggest adapting current laws, such as those covering libel, defamation, identity fraud, or impersonating a government official.

## Using Synthetic Media to Get Around Copyright Laws

In many countries it is illegal to plagiarize someone's original content. You might remember the 1989 pop-rap crossover hit "Ice Ice Baby" by Vanilla Ice. He sampled David Bowie and Queen's collaboration "Under Pressure" (you know the base line hook: da-da-da---da-da-da-dum) but didn't get permission first. He tried to get around copyright law saying that he added a beat between notes (Ice's version: da-da-da...da-da-da-dum, DA---da-da-da---da-da-da-dum) and made it a distinctly different song. The case settled out of court, but it shined a light on how U.S. copyright laws were created to protect the financial—not creative—interests of artists. What if someone created a slightly altered copy of you for promotional commercials? For example, if your likeness was edited to include facial hair and a pair of glasses you don't have in real life, and then used without your permission—would those details eliminate the legal requirement for consent?

## Synthetic Media Marketplaces

We already got a taste of what our future synth media marketplaces will look like. In 2018. a subreddit dedicated to publishing deepfakes morphed into a makeshift marketplace. Users were volunteering to create deepfake videos of celebrities, co-workers, family members, neighbors, and enemies in exchange for crypto-currency. In the near future, marketplaces to commission, buy, and sell synthetic media, as well as their attributes, will be visible on the dark social web.

## Truth Decay in an Era of Synthetic Media

In 2021, we expect to see synthetic media technologies further commercialized and made widely available. But without the infrastructure in place to help consumers distinguish between synths and humans, the likelihood of misinformation campaigns remains high. Synthetic media could be weaponized by governments, activist groups, and individuals, and could be treated the same as all other internet content, showing up in search results, on our smart speakers as audio content, on our connected TVs, in our inboxes, and throughout social media. Synthetic media can be particularly inflammatory in the political realm, where both sides of a polarized public are motivated by social media algorithms to share and engage with sensationalized content without necessarily verifying its authenticity.


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# News & Information

# Expert Insight

## How the News Industry Must Evolve to Fit into Daily Life

**Ebony Reed**

New Audiences Chief,
Wall Street Journal

Audiences have developed new behaviors and habits as a result of the global pandemic. At the same time, we are on the cusp of a revolutionary opportunity to transform news experiences with faster internet speeds through the eventual mass adoption of 5G, which is still in its early days. These changes—behavioral, societal, and technical—mean we are better positioned to create news that fits more seamlessly into daily life. It also means we have to solve problems for users and help them verify the accuracy of the information they consume.

### News + e-commerce

More people are on their devices—like computers and smartphones—and not just for information consumption, work, and entertainment. A growing number of people—more than 200 million in the United States—are shopping and living online. We need to integrate news into the experiences and activities that people are already doing. We should consider doing this on our owned and operated platforms. This will also involve reassessing the actions we allow audiences to take on news platforms.

Some innovators and academics, including me, had proposed that smart homes offered new plat-

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forms for journalism. But we've found the masses still consume digital news mainly on computers and smartphones. While offering products for purchase on news sites isn't a new concept, we now have a larger base of people who, as a result of the pandemic, may be open to buying or even expecting it. We know that allowing people to take actions on our platforms can create a stickier experience and help reduce audience churn, and we must find ways to continue to leverage this trend.

### Empowering audiences

News literacy initiatives need to offer more two-way interaction with audiences and empower them to determine if information is trustworthy, accurate,and from a reliable source. This is an essential public service. Clear plans and strategies are needed to show audiences how to use technology to trace the provenance of news and information. Some news companies define words and link to previous coverage to offer more transparency, but not enough initiatives show audiences what to question, how to verify information, or how to track story developments on their own. Is it worthwhile to experiment with blockchain technology or use traditional docs to help audiences track news stories? Will citizens who can track changes in news begin to trust journalists more? We need to focus on how to empower audiences as we create news literacy projects.

### More immersive experiences

As 5G gains adoption and creates faster and more stable connections (even if it takes a decade to fully take hold because users need to upgrade devices), we are already asking how to build more immersive news experiences. This is a unique opportunity to bring audiences into actual news events. How would it have felt to experience, in almost real time, all of the marches for equality and social justice across the world during the summer of 2020? How will the masses react when they can regularly experience news, not just read, listen, or view it? And how will that impact our real-time conversations, opinions and lived experiences when we can all experience—not just watch—certain events in near real time together?

### Service journalism

Offering audiences services and utility is another way we can connect with and help them. People want to know how to write a standout cover letter, write a resume, and grow their money. Others may want to know how to lose pandemic pounds. We need to create content answering audiences' immediate questions and help them solve challenges they are facing. We can already see what audiences want to know based on what they search for online and by asking them to tell us. As we think about growing the community around journalism, how we help people should remain a core focus. This is also a unique strength that positions news organizations to have a lasting impact with audiences. After all, don't you recall the last time someone helped you?

**

*Ebony Reed is New Audiences Chief at the Wall Street Journal, a member of the strategy team and leading efforts to expand the Journal's reach. Prior to joining the Journal, she was director of innovation at the Donald W. Reynolds Journalism Institute and an associate professor at the Missouri School of Journalism.*



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2ND YEAR ON THE LIST

# Cancel Culture and Accountability Politics

Social media has created supercharged cycles of outrage, boycott, and backlash.

## KEY INSIGHT

**Powerful people frequently dismiss justified protest and credible accusations as "cancel culture" to evade consequences for their actions. On the other hand, certain "cancellation" campaigns, waged via social platforms but with real-world repercussions, are misguided or vindictive attempts to discredit or exploit those in the spotlight.**

## EXAMPLES

"Canceling" can come in many forms: calling out, deplatforming, censoring, boycotting. It can happen to celebrities, but private figures can get caught up, too. New York resident Amy Cooper, for example, faced criminal charges after being filmed calling 911 to falsely accuse and harass a Black man, and she was also fired from her investment firm after public outcry and viral bad press. Online vigilantism is sometimes the only way to hold people accountable in a world that doesn't always achieve justice through traditional means, but not every call for sanctions is equal in scope or stakes. YouTube personalities have attempted to cancel each other over personal slights. Former President Barack Obama is one of many voices pushing back against the culture of calling people out online. "The world is messy; there are ambiguities," he said last year. "People who do really good stuff have flaws."

## DISRUPTIVE IMPACT

Every day we create a robust, lasting record of our lives thanks to the proliferation of connected devices and cheap data storage. As social norms evolve, those records will memorialize choices, messages, and actions that don't necessarily sync with our future selves, or our future culture, providing ample fodder for character assissination. As a society, the question is whether we will let those who transgress learn from their mistakes: What can someone do to repent when they do harm? What past acts are irredeemable? And who gets to decide when atonement is complete? The person or community who was violated? The transgressor? Their allies online?

## EMERGING PLAYERS

- Electronic Frontier Foundation
- Rep. Matt Gaetz (R-Fla.)
- Rep. Marjorie Taylor Greene (R-Ga.)
- Facebook
- YouTube
- Twitter



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1ST YEAR ON THE LIST

# Sensory Journalism

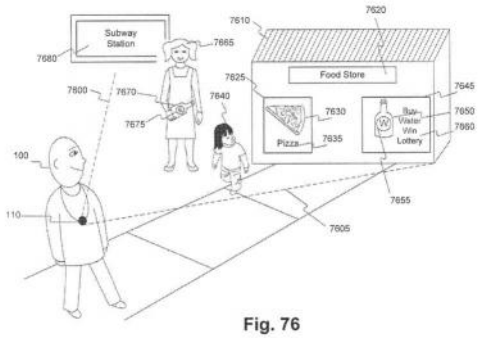


Fig. 76

The OrCam MyEye has patents that describe "lifelogging"—storing details about what individuals have done, where they've been, and who they've met for recall later.

## KEY INSIGHT

**Wearable devices will change everything we know about user interaction. Glasses, headphones, and other wearables will integrate directly with a user's sense of sight, hearing, and touch. Instead of developing media for a particular screen size, storytellers are going to need to optimize for individual users' senses.**

## EXAMPLES

The OrCam MyEye, a small camera that clips onto any pair of glasses, is a simple wearable device that recognizes what it "sees" and describes it to the wearer. It's ideal for helping visually impaired people interact with the world around them, such as hearing a menu read aloud. But OrCam's aspirations are much bigger: Patent filings describe methods for "lifelogging"—storing details about what an individual has done, where they've been, and who they've met for recall later. Facebook's Project Aria is building wearable devices and testing them in the real world with hopes of defining what is useful, meaningful, and relevant when a device integrates with a user's senses. This is a seismic shift for storytellers: Experiences won't be constrained by the size of a screen or the shape of a device, but will be bespoke to each user.

## DISRUPTIVE IMPACT

Storytelling that integrates with a user's perception could foster empathy and unlock new ways to understand the world—but it could also be manipulated to create sensory clickbait. Journalists will need to find new ways to deliver the news, but they must hold tech companies accountable as this technology develops. There is essential reporting to be done on how wearable devices will be compatible with different types of bodies. Will sensory integration work equally well for people of all genders? People of color? People with disabilities?

## EMERGING PLAYERS

- OrCam
- Facebook Project Aria



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2ND YEAR ON THE LIST

# Geography Reshapes the Virtual World

New York legislators passed laws now governing how content can be published and shared in the state.

## KEY INSIGHT

**In the internet's first two decades, information crossed borders freely. Now local, state, and national governments are creating a complex patchwork of regulation that assigns internet users (and their data) different rights in different places.**

## EXAMPLES

The California Consumer Privacy Act (CCPA) gives Californians the power to stop businesses from selling their personal information and a GDPR-style right to have information deleted. Businesses that serve Californians—even if they're not based in the state—are required to be compliant as of January. Washington passed a law strengthening the definition of personally identifiable information in the state and shortening the window companies have to notify consumers and the state attorney general after a data breach. In New York, legislators passed the Stop Hacks and Improve Electronic Data Security Act to increase the types of personal information covered by the state's data breach reporting law. New laws will give real meaning to the physical geography of where a user accesses the internet, and of where the companies involved are located.

## DISRUPTIVE IMPACT

CCPA and the other state laws on the horizon will impact ad targeting, but watch for major changes in any business that depends on knowing its consumers, like subscription marketing. Without coordinated effort, geographic differences in rights and expectations will continue to proliferate. This could change the economics and operating model for companies that serve customers across international borders (or even across state lines in the U.S.). Established tech platforms and multinational organizations will 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.

## EMERGING PLAYERS

- European Union
- U.S. Federal Communications Commission



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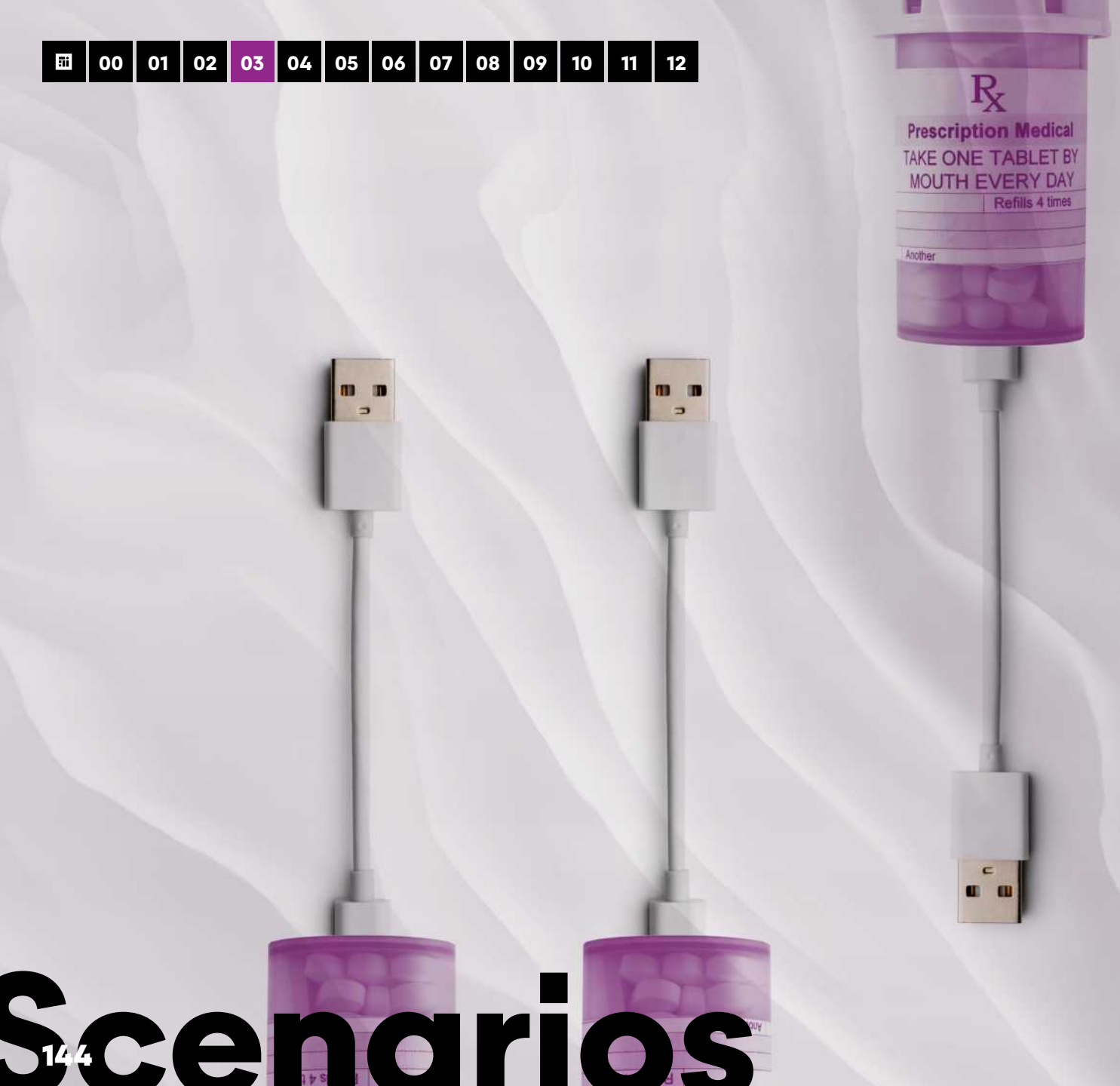


## Reality Prescriptions

**Near-future pessimistic scenario**

The more time we spend in virtual worlds, the more we lose touch with reality. It's not our fault. These virtual worlds are designed to keep us plugged in with strategically timed dopamine hits. Doctors and mental health experts raise the alarm as they witness the side effects of digital addictions and overdose symptoms. Too many people are losing sleep, straining their bodies, and neglecting loved ones. To combat the rising digital addiction epidemic, health care practitioners begin to prescribe doses of reality. Once recorded in your digital health records, these reality prescriptions commandeer your devices. Restricted usage, diminished potency, and even full-on lockouts limit or prevent your time online. But addictions are hard to overcome, and some patients resort to contraband and DIY devices to get their fix. Reality rehab might be the only solution, but the digital dope keeps beckoning addicts away.

# Scenarios



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2ND YEAR ON THE LIST

# The End of Attention Metrics

Brand safety and ad fraud protection will be top advertiser priorities in 2021.

## KEY INSIGHT

**The attention economy, which spawned listicles and tweet roundups, isn't as easily measured as previously thought. Measuring how consumers allocate their attention depends on how you count—and who is counting.**

## EXAMPLES

Researchers estimate that more than half of web traffic is fake. Fraudulent traffic is generated by bots that can fake clicks and by click farms in which a single user can interact across scores of devices simultaneously. Nevertheless, vast portions of the digital economy are built around quantifying how users consume media online.

Beyond different ways of counting, there's also outright fraud online. Schemes to manipulate metrics follow the money: MadHive, a digital TV advertising company, estimates that 20% of video ad requests are fake. This is a serious problem for both publishers that rely on ad revenue and for advertisers that need to satisfy client metrics.

## DISRUPTIVE IMPACT

As mainstream browsers increasingly block third-party tracking cookies by default, it will be harder to connect individuals to their actions across the web. Digital marketers and advertisers must find new ways to quantify the impact of their work—and to ensure that their partners trust their metrics.

## EMERGING PLAYERS

- Google Analytics
- Chartbeat
- Facebook
- Interactive Advertising Bureau



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6TH YEAR ON THE LIST

# Digital Frailty

Patrick Soon-Shiong bought the Los Angeles Times in 2018. The Wall Street Journal reported that Soon-Shiong was trying to sell the company in February 2021.

## KEY INSIGHT

**Digital frailty is when digital assets are impermanent or easily compromised by technical glitches.**

## EXAMPLES

Digital frailty is evolving from a flaw into a feature: This trend emerged as media was erased from the web because old sites were no longer maintained. It's still problematic when information with archival value is lost, but more systems are being designed to encode impermanence as users adapt ephemeral tools like Instagram stories or messages that expire within a set time frame. There's also risk when organizations turn to external tools or services to manage their prominent programming. Storify was a popular tool for aggregating social media posts around a major news event. A team of journalists working for Reported.ly, a now defunct experiment run by First Look Media, won a 2015 Online Journalism Award for reporting on the shooting at Charlie Hebdo magazine in real time. All that reporting lived on Storify but was lost when the platform shut down in 2018.

## DISRUPTIVE IMPACT

Sometimes new technology obviates the old before anyone has had a chance to convert files or develop archives. The Internet Archive and others try to create snapshots in time, but the services can struggle with dynamic sites that heavily rely on JavaScript. While there's archival value to the files we post online, users are increasingly choosing ephemeral formats to share via Instagram Stories and Snap. How will future societies learn from the past if they cannot study the first draft of our present history? Do we have an obligation to preserve the digital conversations shaping society? Should we be working harder to ensure that digital archives aren't lost?

As we develop expectations for what should be archived, we must consider the risks of creating an indelible record: What should happen to posts shared by minors to social networks or student assignments posted to a school's digital portal? Do young people have the right to a blank slate when they reach adulthood, or should they be held accountable for ideas they try on for size on the way to maturity?

## EMERGING PLAYERS

- Internet Archive
- Amazon Web Services
- Microsoft Azure
- Google Cloud



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2ND YEAR ON THE LIST

# Sensitive Content Warnings

Some episodes of "The Muppet Show" now come with sensitive content warnings.

## KEY INSIGHT

**Sensitive content warnings now appear regularly, as a way signaling that the information about to be conveyed may upset or aggravate certain readers, viewers, or listeners.**

## EXAMPLES

Several companies, including Disney and Dr. Seuss Enterprises, are assessing archival content for representations of culture, religion, gender, and ethnicity. As of February 2021, several Dr. Seuss books, which depict racist imagery will no longer be published. A 2019 survey of Seuss' works found that just 2% of human characters were people of color, they never had dialogue, and they were likened to servants or animals. Dr. Seuss Enterprises said that the books—published in the 1930s to the late 1970s—"portray people in ways that are hurtful and wrong." On the Disney+ streaming service, several episodes of "The Muppet Show" now include warnings that episodes contain outdated cultural depictions. Similar disclaimers precede streams of "Lady and the Tramp," "The Jungle Book," "The Aristocats," "Dumbo," "Peter Pan," and "Swiss Family Robinson."

## DISRUPTIVE IMPACT

Signposting sensitive content, or removing it completely, will continue this year, sparking controversy and debate about cancel culture. A cultural shift is underway in the U.S. that will result in permanent changes.

## EMERGING PLAYERS

- American Association of University Professors
- Modern Language Association
- National Coalition Against Censorship



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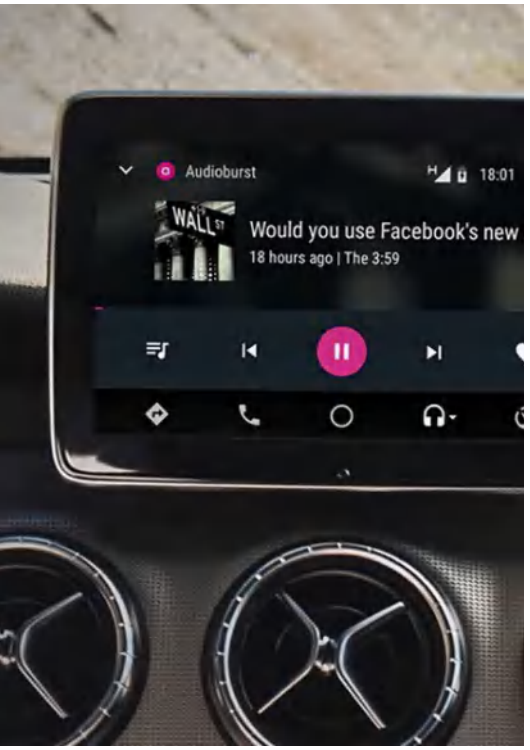
4TH YEAR ON THE LIST

# New Search Interfaces




Audioburst wants to be the Google of radio.

## KEY INSIGHT

**Most people still find the majority of information they consume through search, and indexing new content types for wearable and spoken interfaces is proving challenging.**

## EXAMPLES

The line between old-fashioned webpages and new forms of content—from Instagram chats to Alexa conversations to mixed reality characters—is blurring. Companies like Trint help publishers transcribe audio to make it more searchable by traditional crawlers, while other startups like Audioburst are trying to use technology to actually "listen" to data previously locked into a waveform and make these units of audio more navigable. Audioburst's technology ingests and analyzes audio and uses natural language processing to understand its contents, contextualize it, and make it all searchable.

## DISRUPTIVE IMPACT

It will be a while before we have a universal search agent that crawls through conversations, games, and mixed reality content for the information we seek. Until then, voice search optimization (VSO) will emerge as a way of surfacing relevant content on spoken interfaces. Spatial computing is in its infancy today, but soon consumers might expect to be served only stories relevant to what they are viewing through smart glasses. Searches based on conversation or what a user is looking at will be highly contextual, requiring sophisticated algorithms to anticipate the intent of a query and the relevancy of results.

## EMERGING PLAYERS

- Trint
- SpokenLayer
- Audioburst
- Listen Notes
- Snap



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# Expert Insight

## New Horizons in Book Publishing

**Maja Thomas**

Chief Innovation Officer,
Hachette Livre

My team is always asking how the Hachette Group, an international publisher, can become the most innovative provider of reading and learning. We research how new technologies, partnerships, or business models could expand our reach in an increasingly competitive attention economy.

For most of our proof of concepts, we work with partners large and small to create new experiences and test them with readers. Alternately, we will build our own technology, such a proprietary trend detection tool for identifying various signals on the internet that we use to spot talent and to inform demand-driven book creation.

Our company, Hachette, has widely gained expertise by bringing start-ups in house and learning from them. We've welcomed entrepreneurs specializing in digital-first publishing, the creation of board games and mobile games, brain training applications, and educational games.

Today, as we look forward in 2021, we identified several strategic publishing opportunities. One of them: the chance to reach and engage younger readers, who have come to expect some level of interactivity and agency from entertainment activities. TikTok, Roblox, and Fortnite has shown how people love to shape and share their experiences with friends and co-creators.

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> We've harnessed augmented reality to give readers the ability to scan the front and back covers of Orbit science fiction books and magically animate the covers or unlock a special video in which authors seem to speak directly to them.

We've harnessed augmented reality to give readers the ability to scan the front and back covers of Orbit science fiction books and magically animate the covers or unlock a special video in which authors seem to speak directly to them. Similarly, our educational publishers created ways for students to manipulate 3D objects in a textbook, and our travel guide divisions created an augmented reality treasure hunt among monuments in Paris that leverages the content and expertise usually locked in a book while the consumer is out "in the wild."

We've incubated startups that offer new forms of content creation, such as a collaborative writing platform that allowed authors to react together to pandemic isolation and provided a writing contest for high school students to connect while they were socially distanced.

We also strive to connect to readers on the platforms they haunt: creating chatbots of characters on social media platforms, teasing new book titles on TikTok, or promoting paid newsletters from authors to their most avid fans who opted in to receive exclusive offers.

We also believe that consumers will increasingly adopt the audio interface, and that it is leading the way to ambient commuting. By adapting books that have already been published, we've re-imagined stories that can work on smart speakers by using voice activations to let a child choose their own adventure, just by speaking a wish out loud.

Hodder Studio has created audio originals—also known as active audiobooks—that encourage listeners to garden or cook as they listen. They've published *Seeds from Scratch* and *Breaking Eggs* for people that want expert audio companions guiding them along as they learn.

Many of Hachette imprints have also created podcasts to promote books, genres, imprints, and authors. The early enthusiasm around Clubhouse, the audio chat social network, shows that the connections that can be made using the human voice are just starting to be more fully explored.

**We believe that data aggregation and analysis, as well as AI, will continue to play a big role in publishing in the near future.**

Data is key to understanding who our readers are and what they enjoy and what they want. Reader analytics, then, has been the focus of many of our efforts. We've set up online communities where we can A/B test covers, titles, and descriptions, and measure engagement by time spent reading, completion rates, and qualitative surveys.


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> By adapting books that have already been published, we've re-imagined stories that can work on smart speakers by using voice activations to let a child choose their own adventure, just by speaking a wish out loud.

We've designed experiments that analyze visual "heat maps" showing where the human eye goes on covers and marketing materials, and data aggregation (and AI) to identify cover trends in upcoming publishing seasons.

Even fine-grained data about what is *in* our books is also sometimes surprisingly hard to access. That has led us to create a "tagging factory" in France to enhance the metadata around titles, word clouds extracted from full texts in the U.S., and book recommendations created using "verbal DNA" patterns in books.

We should soon be able to use AI to alert a publicity team to focus on a book from Hachette's enormous backlist that is newly relevant due to a news event.

**In the future, artificial intelligence will push publishing to evolve even further.**

GPT-3 has just begun to show us how autogenerated text may be able to extend story worlds and allow personalization or customization at scale. Although AI and data will never replace the creativity of writers or the expertise of publishers, they can be used as powerful tools by those that understand their capabilities.

**As sales continue to move online and digital formats gain traction, new platforms will arise to support authors, independent booksellers, and publishers—and to entice new readers.**

All-you-can-eat subscription models, we think, make no sense for books—a long format with deep engagement and commitment that isn't usually bingeable. However, expert curation, early access, and exclusive content can distinguish subscription services offered by publishers. One example is the Feminist book box being offered by Hachette UK, which curates books from across 10 different imprints.

As the transformation of our business and our lives continues, Hachette will continue to bring delightful stories and useful information to people in formats both traditional and new.

**

*Hachette Livre is an international publisher with a huge variety of publishing segments, and as the director of the Hachette Innovation Program Maja Thomas works to accelerate the company's digital transformation by testing and applying experimental concepts, prototyping new solutions, and spreading a culture of innovation.*



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7TH YEAR ON THE LIST

# Journalism-as-a-service

In January, Rolling Stone announced that it would let "thought leaders" pay $2,000 for the privilege of writing for the magazine's website.

## KEY INSIGHT

**On the fringes, news organizations are beginning to provide journalism as a service, rather than as traditional news products. This model could help develop new funding streams for cash strapped media companies—but without care, it could also erode trust in an organization's core reporting.**

## EXAMPLES

"Journalism as a service" lets news organizations sell on-demand access to the components of their reporting, rather than just the finished product. The clearest example to date comes from ProPublica, which launched a platform for selling data. Journalists compiled and processed the records for their reporting, but the information has uses in other domains. The Markup, a nonprofit journalism outlet reporting on the tech industry, has concentrated on building tools like Blacklight, which lets users see how websites track them, and Simple Search, which shows how paid advertisements influence Google search results. While those tools are distributed for free, they show how journalism could re-orient toward product development. In January, Rolling Stone showed how this trend might go wrong, announcing that it would let "thought leaders" pay $2,000 for the privilege of writing for the magazine's website.

## 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 working in the knowledge economy—universities, legal startups, data science companies, businesses, 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 can automatically generate reports using the news org's archives, and more. As those tools are transferred from the newsroom to the business side, however, there is the risk that journalistic ethics are lost, threatening to tarnish an entire organization's reputation.

## EMERGING PLAYERS

- PRX
- The Information
- MIT Media Lab
- ProPublica
- The Markup
- Rolling Stone



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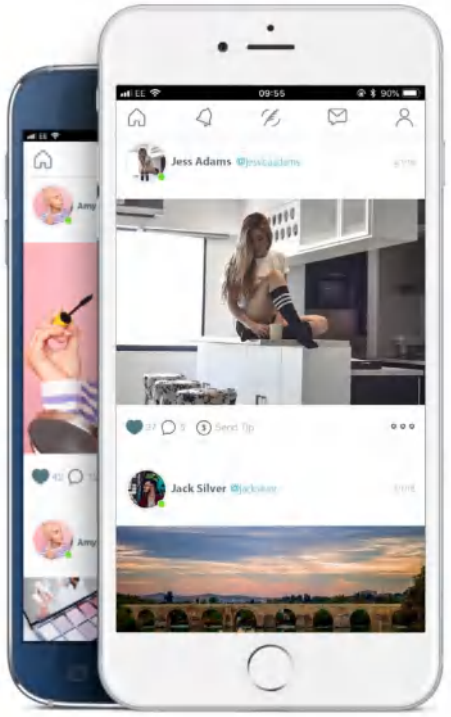
7TH YEAR ON THE LIST

# One-to-Few Networks




OnlyFans expanded the range of monetization for influencers, letting them profit from exclusive experiences and other offerings.

## KEY INSIGHT

**Technology is lowering the barrier for creators to build a direct connection to their audience. Low-cost tools to produce newsletters, podcasts, and niche experiences allow individuals to create personal media brands. One-to-few networks, however, can be a powerful vector for disinformation and misinformation because they lack the editorial safeguards that protect traditional media.**

## EXAMPLES

Online publishing platform Substack lured big names like tech journalist Casey Newton and political columnists Matt Taibbi and Andrew Sullivan away from traditional gigs last year. Substack also gave Glenn Greenwald an outlet when he quit The Intercept, the national security journalism outlet he helped build, in an act of anti-censorship protest. (According to his editors, he was trying to publish without evidence.) Greenwald has the name recognition to thrive on Substack, but he has a track record of grandiose claims, and is now free to publish without oversight. Not all niche networks are high-tech: Last year, Wired reported on anti-vax propaganda spreading throughout insular ultra-Orthodox Jewish communities in Brooklyn via conference calls. WhatsApp encountered a similar problem in 2018, when rumors about child kidnapping spread quickly across rural India leading to a series of mob lynchings, and more recently with the spread of COVID-19 misinformation.

## DISRUPTIVE IMPACT

It's easier than ever for influencers to get paid for their work—and there's growing evidence that consumers will pay creators directly. Services like Substack and Revue offer tools to launch a subscription newsletter, and Twitch can turn a video game habit into a streaming video business. These platforms are also broadening the definition of what influencers can get paid for: Patreon has been used to fund community organizing and anti-racism projects, while OnlyFans enables creators to monetize their influence through soft-core pornography. Some streamers can make a meaningful income, but only by streaming nearly constantly throughout the day, without any time off. Unless the influencer economy evolves to provide paid time off or other benefits, it will be hard for creators to participate in a sustainable manner. Ultimately, all informal networks satisfy a basic human need to connect, but they can also isolate niche communities by amplifying unverified ideas within the group.

## EMERGING PLAYERS

- Substack
- OnlyFans
- Twitch
- Zello
- Patreon



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6TH YEAR ON THE LIST

# Media Consolidation

Chatham Asset Management, a hedge fund with extensive publishing interests, acquired newspaper chain McClatchy out of bankruptcy.

## KEY INSIGHT

**Consolidation continues as media companies try to overcome shrinking margins on ad-supported media. This trend is now spreading from legacy media giants to digital upstarts that need to justify years-old investments that fueled their growth. Concentration of ownership into the hands of a small group of conglomerates threatens diversity in the press and on the airwaves.**

## EXAMPLES

Media consolidation is coming for digital upstarts. After several years of increasing consolidation among legacy publishers, 2020 saw a handful of landmark deals in news media. BuzzFeed and HuffPost merged in November, bringing together two of the biggest names in digital publishing. Like similar deals in legacy media, the tie-up aimed to generate efficiencies and a bigger scale for selling advertising. The concentration of legacy news publishers continued as McClatchy, a 163-year-old newspaper chain, emerged from bankruptcy under the ownership of hedge fund Chatham Asset Management, which owns one of Canada's largest newspaper companies as well as the publisher of The National Enquirer. Chatham beat out Alden Global Capital, another hedge fund. Both funds have a track record for cutbacks at the newspapers they own—one of the reasons that media consolidation is generally associated with weaker local news coverage.

## DISRUPTIVE IMPACT

The U.S. Federal Communications Commission's policy of deregulation under Chair Ajit Pai accelerated the pace—and benefits—of consolidation for legacy companies. But Pai left the FCC on January 20, 2021, and President Joe Biden will appoint a Democratic majority to the panel. Watch for major swings on key regulations like net neutrality, and for disruptions to news coverage in regions with recently consolidated newspapers. Because nearly every major newspaper chain in the United States has seen some consolidation in the last year, this trend will likely impact your region if you live in the U.S.

## EMERGING PLAYERS

- Vox Media
- BuzzFeed
- Chatham Asset Management
- Alden Global Capital
- Sinclair Broadcast Group
- Center for Innovation and Sustainability In Local Media at the University of North Carolina, Chapel Hill



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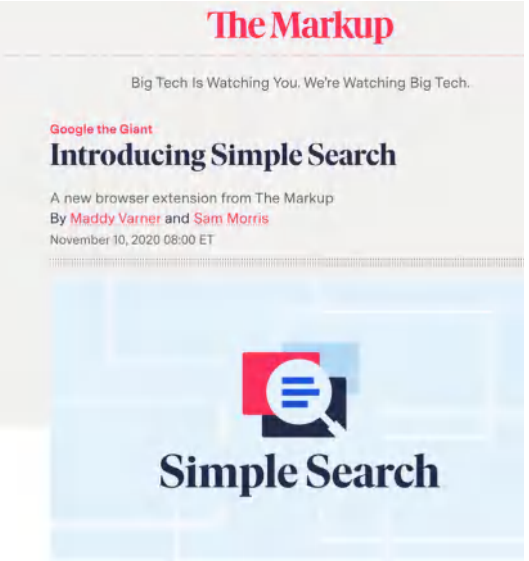
7TH YEAR ON THE LIST

# I-Teams for Algorithms and Data




The Markup built a browser extension called Simple Search that helps users differentiate between "traditional" search results and ads or other results.

## KEY INSIGHT

**The best journalism reveals hidden truths and keeps those in power accountable to the public. Increasingly, that means unpacking how algorithms and big data shape our world. 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

The Markup, a news website focused on the societal impacts of big tech and algorithms, began publishing in 2020. The startup distinguished itself with publishing tools like Blacklight, a real-time privacy inspector, and Simple Search, a browser add-on that removes sponsored search results. Like the Online Political Ads Transparency Project, a New York University initiative that aims to expose how political Facebook ads targeted different users, The Markup's tools are meant to make it easier for laypeople to see how they are tracked and targeted online. The New York Times Visual Investigations unit made a splash in January 2020, using crowdsourced video to re-create the exact moment that an Iranian missile shot down a Ukranian airplane. That report required fusing multiple disciplines to synthesize a conclusion that undercut the Iranian Air Force's original narrative about what had happened.

## DISRUPTIVE IMPACT

News organizations need reporters who can work collaboratively in teams with diverse skills, from explaining technical concepts and reverse engineering code to developing sources and processing geospatial information. As technology advances, it is harder for laypeople to understand how systems function—even as those systems become more deeply embedded in the fabric of our society. Understanding where information comes from, how it spreads, and the impact it has—not to mention explaining the outcomes of algorithmic decision-making—are central responsibilities for journalists who wish to hold powerful systems accountable. Investigating algorithms has never been more important than it is now.

## EMERGING PLAYERS

- The Markup
- Bellingcat
- Washington Post computational journalism team
- 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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2ND YEAR ON THE LIST

# The Subscription Economy Matures

Video games like Fortnite create an ecosystem of rewards that entices users to spend.

## KEY INSIGHT

**A proliferation of content competes for audiences' time and money, opening new opportunities for media companies while also risking that the abundance of subscription options could overwhelm consumers' willingness (or ability) to pay. Without entrepreneurial thinking and business model innovation, news organizations may not keep up with emerging media.**

## EXAMPLES

Whether it's subscriptions, memberships, or donations, we're living in the age of audience revenue. But the subscription economy is bigger than news paywalls, streaming video services, and direct-to-consumer offerings: Soon, more consumers will be asked to pay for virtual fashion, XR experiences, and gaming. Software-as-a-service companies like Piano and Pelcro make launching a subscription or membership program relatively easy. Keeping subscribers is harder: Subscription service platform Zuora reports that media businesses have an average annualized churn rate of nearly 34%, the highest of any sector studied, and on-demand streaming services face even higher rates of subscriber loss than news media, according to The Information. Meanwhile we're living through the first major recession since the launch of most digital subscription programs, with consumer spending on "other services" such as subscriptions dropping 17% in the second quarter of 2020, and remaining far below pre-pandemic levels into 2021.

## DISRUPTIVE IMPACT

Every subscription business has a broad set of competitors. Local newspapers, for example, aren't just competing against The Washington Post and The New York Times—they're competing for time and share of wallet with every other audience-funded business. To track the future of subscriptions, watch gaming platforms like Fortnite, which is free but boasts an ecosystem of in-game purchases that successfully entices users to spend—how many news subscriptions can honestly say the same? The growth of the subscription economy also raises important questions around access and equity. As Heather Bryant, a respected journalist, observed on Twitter during the U.S. presidential election: "Arguably one of the most critical events in the modern history of this country is happening with the election right now and most of the contextual analysis is behind registration boxes and paywalls while all the misinformation and conspiracies are a free, easily accessed buffet."

## EMERGING PLAYERS

- Fortnite
- Roblox
- The Membership Puzzle Project
- Scroll



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7TH YEAR ON THE LIST

# Trust in Media

Trust in media is at an all time low.

## KEY INSIGHT

**The spread of misinformation will continue until platforms and news organizations adopt norms and standards for accountability and trust.**

## EXAMPLES

A healthy dose of skepticism makes for a strong electorate. But deepfakes, intentionally misleading stories, and salacious content posted by political operatives, hackers, and foreign governments have led to increased calls for new methods to rebuild our trust in the media. In February 2021, Twitter said that it would apply labels to tweets containing misleading information about COVID-19 vaccines, and while Facebook said that it would ban vaccine misinformation, the platform struggled to manage a deluge of fake health data and conspiracy theories.

## DISRUPTIVE IMPACT

Edelman's annual trust barometer revealed a sobering reality in America: for the first time, trust in traditional media dropped below 50%. Trust in social media hit an all-time low of 27%. The study found that 58% of Americans think that "most news organizations are more concerned with supporting an ideology or political position than with informing the public." When Edelman re-polled Americans after the 2021 inauguration of President Biden, the numbers had deteriorated further: only 18% of Republicans said that they trust traditional media. As platforms come under increased scrutiny this year for issues related to antitrust, we expect to see demands for transparency and traceability.

## EMERGING PLAYERS

- Google
- Facebook
- Twitter



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6TH YEAR ON THE LIST

# The First Amendment in a Digital Age

Federal courts are divided on how the First Amendment applies to social media.

## KEY INSIGHT

**The First Amendment shapes how platforms and publishers think about the design, development, and implications of content distribution. First Amendment legal protections are broad in scope but limited in geography; they only apply in the United States.**

## EXAMPLES

Constitutional law often lags behind technology, taking time to adapt and evolve as historic concepts are applied to new situations. In the past year, platforms have removed individual posts and in some cases deleted the accounts of people posting hate speech, intentionally misleading information, or calls for violent attacks. In 2021, Amazon Web Services removed far-right social network Parler from the cloud in the wake of the attack on the U.S. Capitol. Social media sites aren't modern-day public squares: Tech companies set the rules and shut off megaphones. While the First Amendment's protections in the U.S. are generally broad, its scope is limited in an interconnected world.

## DISRUPTIVE IMPACT

This year, First Amendment rights and protections from Section 230 of the Communications Decency Act will be debated, though we may not see any concrete decisions. Brands, news organizations, political movements, and big tech companies will continue to face challenges.

## EMERGING PLAYERS

- American Civil Liberties Union
- Electronic Frontier Foundation
- U.S. Federal Communications Commission
- Knight First Amendment Institute at Columbia University



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## AutoINcorrecting History

**Near-future catastrophic scenario**

We marvel at how simplistic the deepfakes of 2021 were. What began as a curiosity to see our ancestors move and speak quickly morphed into a new breed of deceptive technology designed to cancel cancel culture. We've resurrected people and put words in their mouths, edited their personalities, our relationships with them, and ultimately clouded our memories of the lives they lived. We are told that politicians caused great harm—but now, we can't remember what it was, or why people were so mad at the time. With their digital extensions scrubbed, they all seem like rational, likable people.

# Scenarios



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# Application

## STRATEGY

The multiverse, along with shifts in content distribution, will eventually affect an organization's reputation, its messaging, and some of the regulatory protections under which it operates. Chief strategy officers should engage more closely with others in the C-suite, especially chief technology officers, chief marketing officers, and chief innovation officers to develop a longer-term strategy and vision for the organization.

## INNOVATION

Synthetic media and content can be used for new product ideation, to test designs, and to help anticipate what's on the horizon. Given the complexity of new media technologies, chief innovation officers must consider alternative uses of what their teams develop: Once a product hits the marketplace, it could be used to spread misinformation or cause harm.

## R & D

Synthetic media can be additive to the traditional R&D process. Teams making use of digital twins, experimental digital extensions, and other forms of new media can accelerate vital research, especially in urban planning, mobility, and health-related fields. For those working in creative industries, a transformation is underway, which will unlock new business opportunities and shape the future of media and entertainment.

## RISK

We are entering a new, and very complicated, field of intellectual property law. This leads to thorny questions about an organization's legal rights to the content it builds and licenses. Chief risk officers should explore dimensions of intellectual property in an age of augmented media. There are longer-range implications to consider, including brand safety and consumer trust.



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# 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 new media technologies improve our operations?

Our manufacturing processes?

Our product lines?

2

What aspects of our business could be disrupted by synthetic media or shifting news models?

Are we adequately planning for the longer term?

What assumptions must hold true for our current strategy to succeed?

3

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?



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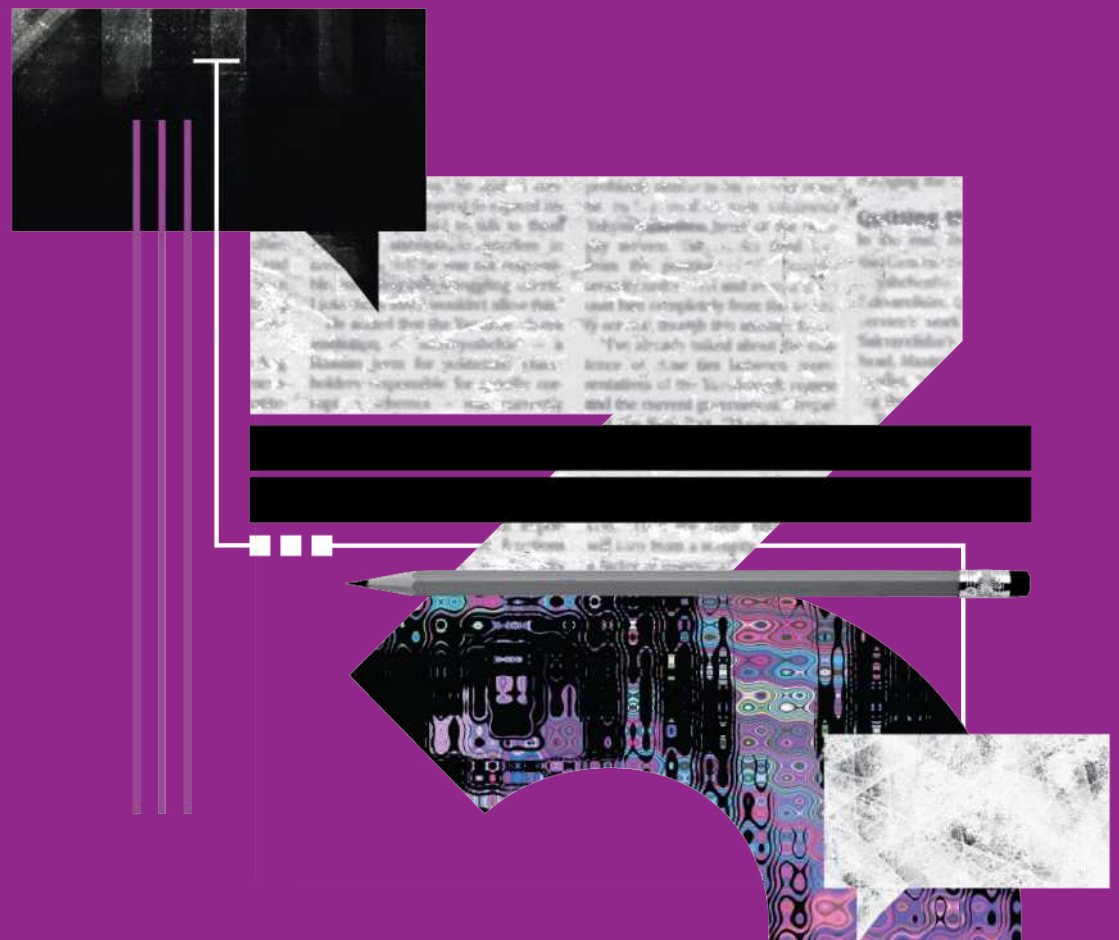

Future Today Institute

Volume 4 of 12

14th Annual Edition

# 2021 Tech Trends Report

Strategic trends that will influence business, government, education, media and society in the coming year.

- Work
- Culture
- Play

Future Today Institute

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# Work Culture & Play Summary

- A tech exodus from Silicon Valley has redistributed a highly-skilled workforce to other parts of the U.S.
- Companies are rethinking long-term investments in office space.
- 69% of companies will reduce their real estate footprint because of COVID-19.
- The global pandemic condensed a decade of digital transformation into a few months.
- Black tech professionals are paid, on average, $10,000 less than their white colleagues.
- Newly-remote workforces rely on video conferencing systems, messaging platforms, networks and home routers that aren't necessarily secure.
- Virtual luxury fashion moves from fringe to mainstream in 2021. Affordable digital clothing will be available this year.
- Celebrity makeup artists are selling AR filters to use in place of traditional makeup in video conferences and social media posts.
- As the eSports ecosystem grows, new academies are launching to recruit and train prospective professional players and coaches.
- E-doping is already an issue in professional eSports leagues, where Adderall and Ritalin are banned substances and using a cheat-code can get you banned for life.
- As genome sequencing becomes more affordable, some biohackers are using DNA results to nutritionally manipulate their bodies.
- From neuroenhancers to sextech, the market for digital and high-tech vices is growing.



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# Work

1ST YEAR ON THE LIST

# The New Hybrid Workweek

With offices unlikely to ever return to their pre-pandemic capacity, floor plans will be reworked to accommodate hybrid in-person and remote meetings.

## KEY INSIGHT

**When the COVID-19 pandemic displaced office workforces around the world, managers and employees had to rethink how, where, and when they could carry out the responsibilities of their job. Having now adapted to remote work and new digital tools, the question remains: Will things ever return to business as usual?**

## EXAMPLES

Work routines have shifted dramatically in the last year, creating new norms and accelerating change, with effects expected to endure long after the pandemic has subsided. Companies like Facebook, Twitter, Square, Shopify and Slack have already pledged to allow employees to work remotely even after lockdowns and social distancing restrictions are lifted, paving the way for hybrid virtual and in-person workforces at scale. Google is exploring a model wherein workers work three days a week in the office, and the other two remotely, either working from home (WFH) or working from anywhere (WFA). It is also important to note that these changes primarily affect white collar industries—most manual laborers, service industry workers and others do not have the luxury of working remote.

## DISRUPTIVE IMPACT

Participating companies are likely to hold less commercial real estate, and revamp remaining floor plans to accommodate lower headcounts and hybrid meetings between in-person and remote workers. The hope is that allowing workers more flexibility will improve their quality of life and mental health, and thus their productivity, however most companies experimenting with these new models do not have data with which to conclusively support that conclusion, and the opposite could prove true. The changes could also blur lines between full-time, part-time, and contract employees, and potentially infringe upon workers' rights. Companies will also have to make important decisions about what remote work platforms and applications to use, as they will likely play a far greater role within the organization as the hybrid workweek becomes standard.

## EMERGING PLAYERS

- The Society for Human Resource Management (SHRM)
- The MIT Center for WorkLife and WellBeing
- Occupational Safety and Health Administration

> Office centricity is over.
>
> — Shopify CEO Tobi Lutke



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1ST YEAR ON THE LIST

# Home Offices Introduce New Cybersecurity Risks

Two-factor authentication (TFA) should be standard practice for workforces accessing sensitive company information from home.

## KEY INSIGHT

**As employees became accustomed to working from their own living spaces over the past year, CISOs raised concerns that insecure and unmonitored home networks could expose the company's proprietary data, trade secrets, video conversations and more to malicious hackers or industry rivals.**

## EXAMPLES

The sudden unexpected shift to remote workforces opened wide gaps in cybersecurity for companies around the globe. Soon after the pandemic sent workers home indefinitely, reports emerged that Zoom, which had quickly become the go-to video conferencing app for countless remote teams, had serious security flaws. From unauthorized users "Zoom-bombing" calls, to questionable encryption, to claims that the company was selling user data, the app was unreliable enough to raise red flags for cybersecurity experts, even leading one computer science professor to declare that "Zoom is malware." Another issue is that housebound employees were much more likely to use personal devices not vetted by corporate cybersecurity officials to access work documents and correspondence, leaving these potentially sensitive assets vulnerable to theft. According to a study by Deloitte, hackers and scammers increased their efforts soon after COVID hit, specifically targeting remote workers.

## DISRUPTIVE IMPACT

Companies that were left scrambling to adapt to pandemic-related workforce shifts may not have properly addressed new cybersecurity vulnerabilities. As remote work becomes more widely and regularly practiced, it's time for CISOs to shore up security measures for off-site employees. Reinforcing cybersecurity best practices, requiring two-factor authentication, installing anti-malware software on all machines, increasing privacy settings on home WiFi networks, and even scanning video backdrops for any exploitable information are some straightforward ways to mitigate risk. Another option is to invest in cyber liability insurance. Any companies that handle 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

> Zoom is malware.
>
> — Princeton computer science professor Arvind Narayanan



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# Apps Shaping the Virtual Workspace

Interest and investment in remote work platforms has never been higher, and a crop of lesser known 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.

## Teamflow

Founded by ex-Uber exec Florent Crivello, Teamflow is a remote work application designed to replicate the organic interaction and conversation of a traditional office environment in a virtual setting. Users see their video or profile pic in a bubble that appears on a virtual office floor plan. The user can then move through the digital space using their arrow keys, and approach colleagues' bubbles to engage them in conversation. Users only hear the voices of coworkers whose bubbles are within close proximity, and spatial audio recreates the directional perspective of an in-person chat.

## Gather

Bringing a retro cyber aesthetic to collaboration software, Gather emulates the routines of office life in order to bring structure to the remote work experience. Customizable avatars can be navigated through a 2D virtual office, designed in charming 8-bit graphics reminiscent of '80s console games. Logging in and sitting at a digital desk marks one's arrival and the symbolic start of the workday, and colleagues can gather their avatars in common areas or meeting rooms to conduct work and social interactions.

## With

Opting for a more conceptual approach, With operates on more of an abstract digital canvas, rather than trying to represent the layout of a physical office space. Workers are represented by subtly animated avatars of animals distributed throughout the virtual space, and can drag documents and tools onto the shared desktop.

## Reslash

Most work software is designed for clarity and efficiency, but not Reslash—founder Ashwin Gupta says the platform was founded on the premise that remote coworkers can connect during the workday as they "destroy and create beautiful chaos out of nowhere." The result is a variety of meme-soaked, gif-spangled shared screens, where users are encouraged to make a mess in the name of unstructured creativity. It's hard to imagine this format directly improving productivity, but it does appear to be a fun, cathartic way to interact with your colleagues.

## Sneek

This startup has designed its interface to reflect one specific office habit—dropping by your coworkers' desks to see if they're free to chat. The Sneek app displays your workmates in a grid format, with still images from their webcam updated at regular intervals. Users can scan the grid to see if colleagues are at their desks and appear available, or if they've indicated they are busy and don't want to be disturbed. To initiate a video call with a fellow worker, the user can simply click their image.

## Around

Rather than try to faithfully recreate face-to-face conversations with a fullscreen video interface, Around shrinks participants' videos and places them in the margin of the user's screen, leaving the desktop visible and accessible so that the project at hand can remain the focus. Ultimately the hope is that this format will even the playing field for remote and in-office workers—even teams gathered in a single conference room at the office can log in individually on their devices, so that every participant is displayed in the same format. The app has even developed a feature so that users in close proximity to one another don't experience audio feedback or echo on the call.



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## Managed Meetings

**Near-future optimistic scenario**

Mathematician and computer scientist Alan Turing once proposed a thesis and a test: If someday, a computer could answer questions in a manner indistinguishable from humans, then it must be "thinking." You've likely heard of the paper by another name: the Turing Test. It's been a guiding force in the development of artificial intelligence ever since. Tests built on either deception (can a computer fool a human into believing it's human?) or replication (can a computer act exactly as we would?) do not acknowledge A.I. for what it has always been: intelligence gained and expressed in ways that do not resemble our own human experience. Rather than judging an A.I. based on whether it can or cannot "think" exactly like we do, a new test judges the value of contributions made by the A.I. on its own during meetings. The Meaningful Contribution Test would be passed when an A.I. assistant can help manage a meeting, by pushing back on a small but growing consensus, tactfully argue for an alternative plan and recruit another member of the group to support that alternative.



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# Culture

1ST YEAR ON THE LIST

# Digital Fashion

With the rising popularity of digital fashion, we may soon see virtual wardrobes that help us catalog and coordinate our physical, digital, and hybrid garments and accessories.

## KEY INSIGHT

**With more and more of the developed world's population customizing avatars in virtual realms, and with the fashion industry perpetually under fire for its pollutive practices, the market for digital fashion has a promising future.**

## EXAMPLES

Some of the world's best known designers have gotten wise to the virtual revolution. Iconic Italian fashion house Gucci has invested in a number of digital fashion initiatives, from a free digital closet partnership with avatar platform Genies, to an integration with styling game Drest, to an in-house app called Sneaker Garage, where users can use augmented reality to "try on" the brand's virtual footwear. Other big-name designer labels have similarly seen gaming as their entrée into the digital space, with Hermès launching an equestrian-inspired mobile gaming app, and Louis Vuitton partnering with the massively popular League of Legends gaming franchise. Elsewhere, Dutch brand The Fabricant has established itself as one of the leading digital fashion companies, catching headlines when one of its virtual dresses sold for an eye-popping $9,500.

## DISRUPTIVE IMPACT

The digital fashion market is poised for growth, both for its versatility in online environments and its ability to reduce waste without retailers having to forego sales. Physical garments may soon come with virtual counterparts, allowing users to catalog their wardrobes digitally, and hang on to a version of their garments even after the physical piece degrades. The ability to express oneself freely through virtual styles may help consumers develop more ecologically conscious shopping habits when it comes to real-world items. In time, as AR eyewear becomes commonplace, users may even be able to virtually showcase their digital looks on their person instead of just 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 smart glasses.

## EMERGING PLAYERS

- The Fabricant
- Gucci
- Louis Vuitton
- Dapper Labs

> I truly believe we are going to be the first billion-dollar digital fashion company.
>
> — The Fabricant founder Kerry Murphy



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1ST YEAR ON THE LIST

# Upcycled and Circular Fashion

New production models from fashion retailers look to repurpose existing materials and garments wherever possible, instead of producing virgin materials.

## KEY INSIGHT

**Once the preferred method of DIY designers and niche clothing brands, upcycling and circular, sustainable fashion has matured to the point where it is being adopted at scale by fashion retailers worldwide.**

## EXAMPLES

According to analytics firm First Insight, more than half of Gen Z customers surveyed prefer to buy from sustainable brands, and nearly three quarters are willing to pay more for sustainable products. Big name retailers have taken note, innovating on upcycling and circularity to attract this growing customer base and reduce harm on the environment. Fashion industry waste ranges from its sheer output—tens of billions of clothing products are produced each year, even by conservative estimates—to the consumption of water and even coal. From industry leaders like outdoor clothing brand Patagonia, whose award-winning circular production model is founded on designing pieces to last a lifetime with proper care and refurbishment, to high fashion Parisian label Marine Serre, whose line is constructed of roughly half upcycled materials, sustainable solutions are spreading and accelerating across a diverse range of fashion retailers.

## 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 in the future as the next generation of conscientious consumers matures and their purchasing behaviours shape the industry. More retailers are exploring buyback and recycling programs as well, like H&M's Looop program, which dissembles old textiles to create new products without using virgin materials. Brands that are making the foray into digital fashion often cite sustainability as a benefit, and digital designs will complement responsibly produced real-life garments to form the hybrid fashion industry of the future.

## EMERGING PLAYERS

- ASOS
- H&M Looop
- Marine Serre
- Patagonia
- Reformation

> We don't have to all reinvent the wheel, but brands that don't face these realities of the true cost of apparel and fast fashion, I think they will be left behind.

— Patagonia CEO Rose Marcario



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2ND YEAR ON THE LIST

# Digital Makeup

By accurately mapping and tracking of the face, AI and augmented reality can produce lifelike digital beauty filters that blend seamlessly with the user's movements.

## KEY INSIGHT

**Digital makeup exists at the intersection of facial recognition, 3D mapping, and augmented reality. As AR becomes a part of our everyday lives, digital touchups and expressive virtual makeup will define how we choose to present ourselves to the world.**

## EXAMPLES

Social media platforms including Snapchat and Instagram offer users AR filters that can change their physical appearance in photos and videos. Some are fanciful, giving the user animal attributes or drastically changing their features, but others mimic the effects of makeup, contouring and coloring the face with the aim of improving its aesthetic. Even video conferencing platform Zoom has a feature where users can smooth their complexion for a more desirable appearance. Beauty brands themselves have ventured into the digital space as well. Redken, Avon, MAC and Maybelline offer virtual "try-on" AR apps, saving time and money for those looking to match products to their skin tone when buying online. L'Oreal, meanwhile, has created a line of digital-only beauty products to be used in popular social and video conferencing apps.

## DISRUPTIVE IMPACT

Digital beauty is not merely a consumer perk. It can have a direct effect on business. China's AliPay responded to complaints that customers were put off by their appearance when paying for items via facial recognition camera systems, adding a digital beauty filter to improve the experience. Gaming platforms with customizable avatars and robust marketplaces for in-game purchases are a popular way for beauty brands to test digital products. Unisex skincare label Evenprime created a "skin" for avatars in the fantasy action game Spellbreak, and customers who bought Evenprime's skin serum in the physical world automatically received access to the digital skin. With gaming becoming increasingly popular among women and girls, despite old-fashioned assumptions to the contrary, the gaming and esports beauty market may soon become a new profit center for cosmetics brands.

## EMERGING PLAYERS

- AliPay
- Drest
- Evenprime
- Ines Alpha
- L'Oreal
- Snap
- Spellbreak



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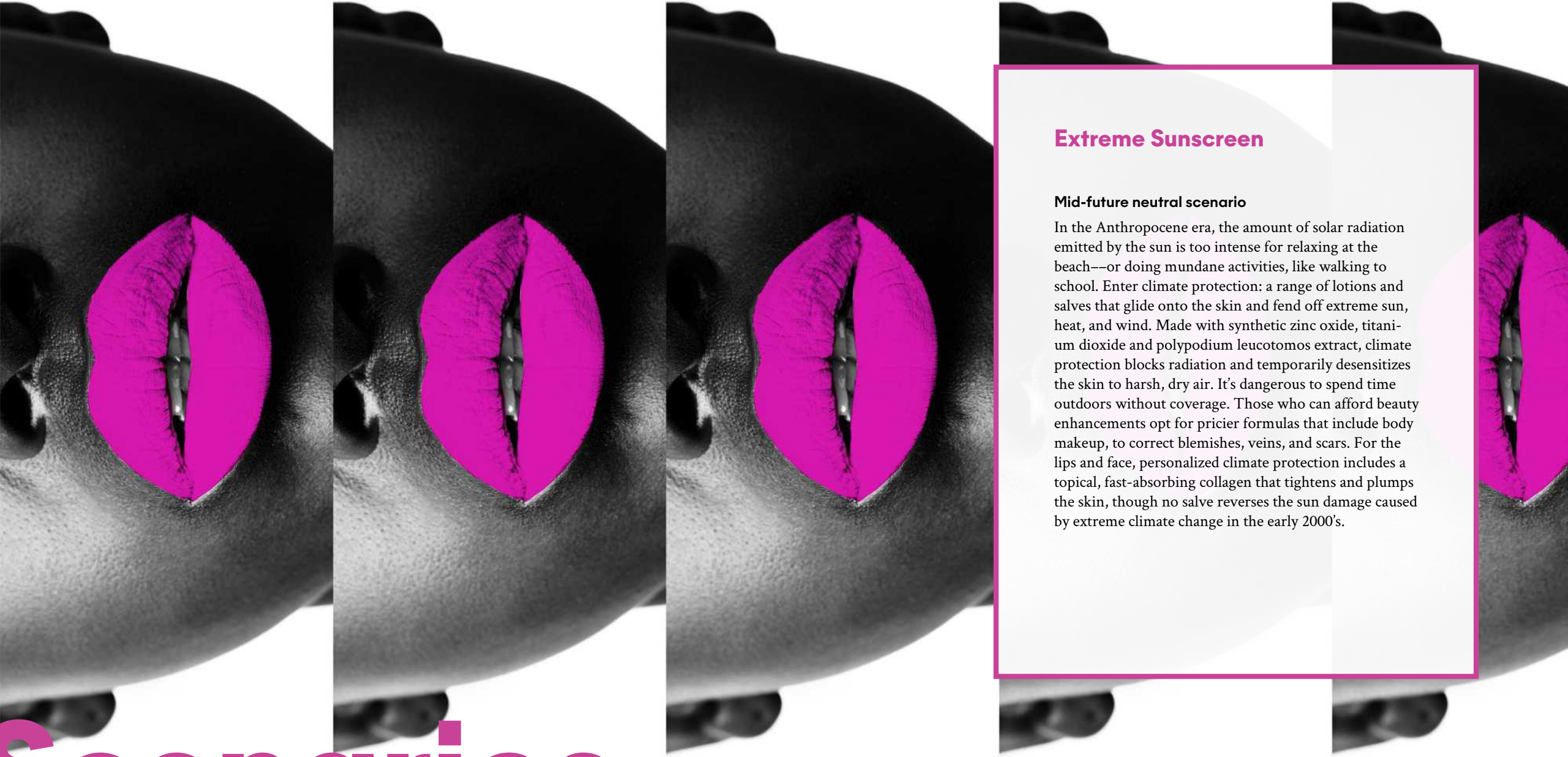

## Extreme Sunscreen

### Mid-future neutral scenario

In the Anthropocene era, the amount of solar radiation emitted by the sun is too intense for relaxing at the beach––or doing mundane activities, like walking to school. Enter climate protection: a range of lotions and salves that glide onto the skin and fend off extreme sun, heat, and wind. Made with synthetic zinc oxide, titanium dioxide and polypodium leucotomos extract, climate protection blocks radiation and temporarily desensitizes the skin to harsh, dry air. It's dangerous to spend time outdoors without coverage. Those who can afford beauty enhancements opt for pricier formulas that include body makeup, to correct blemishes, veins, and scars. For the lips and face, personalized climate protection includes a topical, fast-absorbing collagen that tightens and plumps the skin, though no salve reverses the sun damage caused by extreme climate change in the early 2000's.

Scenarios



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3RD YEAR ON THE LIST

# Vices

CBD gummies are increasingly available in the U.S.

## KEY INSIGHT

**From neuroenhancers to sextech, the unique market for digital and high-tech vices is growing.**

## EXAMPLES

The new crop of vices are digital, high-tech and organic. They were designed to strengthen our mental performance and agility, help us relax, and afford us moments of pleasure.

## DISRUPTIVE IMPACT

A bitter election season, fragile economy and the global pandemic resulted in stress and burnout. Two thirds of adults say that the number of issues America is facing is overwhelming to them, according to a study by the American Psychological Association.

In the past year, as lockdowns forced people indoors and reset our social structures, many struggled to navigate self-care. It's no surprise that we're seeking new ways to escape reality or to enhance our moods.

## EMERGING PLAYERS

- Doppel
- Emotiv
- New Frontier Data
- Thync Kit
- Bulletproof



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# Vices

Puff Bar defied FDA rules in January and began selling its products again online.

## Neuroenhancers

Neuroenhancement devices aim to record brain waves and send feedback. Some promise to help you become more productive, while others are meant to boost your mood. Australia-based SmartCap uses a tracking system with voice warnings and vibrations to keep you alert while on the job. The Muse headband uses neurofeedback to help manage stress and improve athletic performance. The Emotiv Epoc+ and Emotiv Insight and mobile EEG devices monitor your brain activity and analyze cognitive performance. Doppel, which is worn on the wrist, uses electric pulses to augment your energy. The pulsations, which you dial in based on your needs, are supposed to have an effect on your brain similar to that of music. The Thync Kit is a series of electrodes and a triangular device that you stick on to your head—as well as a mobile app synced to your smartphone. It delivers low-grade electric pulses to influence either your sympathetic (fight or flight) or your parasympathetic (rest and digest) nervous system. Of course, this same technology can be used for nefarious purposes. In China, the military and some businesses now use connected headbands and hats to monitor employee brain activity. This emotional surveillance technology is said to optimize productivity—State Grid Zhejiang Electric Power, based in Hangzhou, reported its profits spiked $315 million since using neuroenhancer devices and software to mine, refine, and analyze employee brain data.

## Nutrigenomics

As genome sequencing becomes more widely available and affordable, some biohackers are using DNA results to nutritionally manipulate their bodies. All nutritional decisions--what foods to avoid, what drinks to consume more of, what vitamins and supplements to take—are based on that baseline sequence and real-time metabolic testing. Biohackers consume different combinations of foods based on what they need enhanced: performance, focus, or sleep.

## Nootropics

If you need to manage stress or focus, you might look to "nootropics," cognitive enhancement drugs that promise to help keep you calm and attentive. These dietary supplements have been shown to improve cognitive function—even if they're not officially regulated or approved by the Food and Drug Administration. You may already be taking a few: caffeine, red reishi mushrooms, ginseng, turmeric, ginkgo biloba, and Bulletproof coffee are all popular, while natural supplements like creatine, L-theanine and Bacopa monnieri are also being marketed to help promote mental clarity, focus, and information retention. Synthetic compounds, like Adrafinil and Noopept, last longer and take effect within minutes. By some analyst estimates, the nootropics market could reach $11 billion in America alone by 2024.

## Grinder Biohacking

Most body-machine interfaces, like Elon Musk's Neurolink, aren't ready for the general public yet, but that hasn't stopped some people from experimenting. Grinder biohackers implant RFID tags, computer chips, magnets, data transmitters and sensors in their bodies. Their aim: transverse the human-machine divide, and become more seamlessly integrated with technology.

## CBD-Infused Products

Consumers can get CBD in post-workout smoothies, hand lotions, and even morning coffee. Cannabidiol, otherwise known as CBD, is a chemical compound found in the resinous flower of cannabis. While it's a component of marijuana—one of hundreds, actually—it is far less psychoactive than the better-known THC, if at all. In other words, it doesn't really get you high. As of January 2021, 14 states, Washington, D.C. and three territories have legalized cannabis, according to the


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# Vices

National Conference of State Legislatures, but the federal government's stance on CBD is murky. It depends on whether the CBD came from hemp or marijuana, and every state follows different local laws. CBD has been touted for a variety of health benefits and has been shown in many studies to reduce seizures, especially in children with epilepsy syndromes. Because the FDA doesn't regulate CBD, there aren't yet studies that determine the most effective doses. Most of what's commercially available in infused products like drinks and snacks is very low, but the market is huge: the CBD industry in the United States will be worth $16 billion by 2025.

## CBD-Infused Drinks

Beverages is a growing vertical within the cannabis industry. As restrictions loosen on recreational marijuana use, commercial beverage companies are launching new CBD-infused products, like sparkling water, tea, sports drinks and alcoholic beverages. Constellation Brands, which makes Corona beer, and Lagunitas (a subsidiary of Heineken), are both investing in new techniques to infuse their products with CBD. In some markets, Lagunitas also offers drinks with 10mg of THC.

## Cannabis Supply Chains

The supply chain for cannabis is challenging, and due to federal regulation, the largest logistics companies—Amazon, Fedex, and UPS—cannot legally service vendors. Cannabis brands must become their own first party distributor and must own all of their own logistics systems (vehicles, warehouses, packaging) or else use specially-licensed third-party vendors. That latter category is catalyzing new business growth. Local dispensaries are supporting startups that can take orders, authenticate users, and ensure safe and legal delivery to consumers. Eaze and Greenrush are the biggest players in medical marijuana delivery. Wayv, a B2B cannabis logistics firm, launched its Dynamic Distribution platform, which helps companies in California list themselves as third-party distributors for other brands, and automatically runs compliance checks. This will enable cannabis brands to someday move products within their states more easily.

## Cannabis Compliance Systems

With the industry heavily regulated, it can be difficult for dispensary companies with business units located in different states to keep track of compliance. New A.I.-powered platforms are helping dispensaries meet these sometimes complex compliance regulations.

## Specialized Cannabis CRM Platforms

Unlike traditional CRM or customer databases, marketers in the cannabis space have additional regulations to contend with. Baker is an automation platform that caters to dispensaries, combining e-commerce, distribution, inventory management, texting, and loyalty programs.

## Banking for Cannabis Dispensaries

Banking is a big hurdle for dispensaries and their parent companies. Servicing the cannabis industry would expose traditional financial institutions to federal prosecution. Green Thumb Industries, which operates 50 stores, earned $8 billion last year. But it doesn't have access to banks like JPMorgan and Wells Fargo; instead, it must rely on a constellation of small community banks. However with Democrats in charge of the White House, Senate and House, new legislation could make banking easier for dispensaries.

## Vaping and E-cigarettes

In February 2021, lawmakers held a hearing to determine why the FDA failed to regulate vaping sooner. The Centers for Disease Control and Prevention estimates that 3 million American teenagers vape either tobacco or marijuana, and a newly-identified lung disease called EVALI, short for "e-cigarette, or vaping, product use-associated lung injury" is growing sharply among that cohort. Puff Bar, which was ordered last year to take its fruit-flavored vape products off the market, defied FDA and resumed online sales in January, saying that it no longer uses nicotine derived from tobacco. Instead, the manufacturer uses synthetic nicotine made in a lab. Juul Labs, which dominates the e-cig market and is largely blamed for America's vaping epidemic, voluntarily discontinued its flavored products, with the exception of tobacco and menthol flavors. Many competing brands including Bidi Stick and Blu, offer disposable, pre-charged, pre-filled vaping devices, and they're cheaper than Juul pods.



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# Play

3RD YEAR ON THE LIST

# eSports

Chess grandmaster Hikaru Nakamura has more than 1 million followers on Twitch.

KEY INSIGHT

**The video game industry prospered during the COVID-19 pandemic. While organized competitive gaming has arguably existed for decades, advancements in gaming technology, accessibility, streaming capabilities, and popularity have led to an astronomical rise in its commercial potential and perceived legitimacy in recent years.**

EXAMPLES

Online chess became a streaming obsession last year, due in part to Netflix hit "The Queens Gambit" and to a new generation of streamers on Twitch, the online gaming platform. Between January and September, viewers consumed more than 40 million hours of live-streamed chess. The League of Legends World Championships clocked more than 139 million hours of viewership. Twitch, the primary streaming portal for eSports in the Western world, logged a staggering 17 billion hours worth of content last year, a full 83% higher than its previous record in 2019. (Twitch was acquired by Amazon in 2014.) When Rep. Alexandria Ocasio-Cortez (D-NY) joined high-profile Twitch gamers for a round of "Among Us," the stream broke records: 435,000 viewers watched to see who was the imposter.



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# eSports continued

## DISRUPTIVE IMPACT

Even before the pandemic, 2020 was set to be a blockbuster year in gaming and eSports. New consoles from PlayStation and Xbox weren't just minor upgrades to hardware, they were generational leaps with drastically improved graphics processing and motion control. eSports tournaments weren't held in person, but plenty of tournaments were held and without football games and boxing matches to bet on, eSports betting found wide new audiences last year. In 2020, eSports companies raised more than $2 billion, up 115% in value from 2019, according to Quantum Tech Partners. As audience numbers for eSports continue to climb, platforms will compete to outbid each other for media and streaming rights for events like League of Legends World Championships and Fortnite concerts. eSports will soon rival television as a form of mainstream entertainment because of its interactive and immersive nature. Advertisers are taking notice. Nike sponsors several professional teams. As the sport matures, so will concerns about fair play. E-doping is already an issue in professional eSports leagues, where Adderall and Ritalin are banned substances and using a cheat-code can get you banned for life.

## EMERGING PLAYERS

- 100 Thieves
- Bethesda Game Studios
- Catalyst Sports & Media
- Bayes Holding
- Overwatch League
- Twitch
- Y Media Labs


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1ST YEAR ON THE LIST

# eSports Training Academies

The Collegiate Star League offers college sSports scholarships.

## KEY INSIGHT

**As the eSports ecosystem grows, new academies are launching to recruit and train prospective professional players and coaches.**

## EXAMPLES

Amateurs hoping to make the leap to professional eSports can't just excel at certain games—they need to understand the gaming business, how to manage their time, and how to develop content and interact with fans. Several colleges and universities, including Ohio State and George Mason, offer undergraduate degree programs in eSports.

## DISRUPTIVE IMPACT

eSports pros earn upwards of $250,000 a year, while performance coaches can earn $100,000 or more. Given the market size and projected growth, amateurs hoping to play professionally are seeking practical training. Davon Williams, a computer scientist with the U.S. Army Network Enterprise Technology Command, has launched the Centry Academy of Gaming and Esports (CAGE), an online school that plans to offer degrees in eSports specializations: coach, player, streamer and announcer.

## EMERGING PLAYERS

- High School Esports League
- National Association of Collegiate Esports (NACE)
- League of Legends
- Centry Academy of Gaming and Esports



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1ST YEAR ON THE LIST

# Gaming Subscription Wars

Microsoft Game Pass features hundreds of titles.

## KEY INSIGHT

**Games pose a unique business challenge: when a company has no new console or blockbuster title, players hop over to other platforms. New subscription models hope to keep consumers loyal—and away from competition.**

## EXAMPLES

Subscription models from Apple, Google, Sony and Microsoft are changing the traditional dynamics of games. After spending hundreds of dollars on consoles, players have to shell out $20 - $60 or more on individual games. In a world where mobile phone games cost a fraction of that price, gaming companies have reconsidered subscriptions as a way to generate revenue over longer periods of time. Google launched its game streaming service Stadia in August 2019, with subscriptions to its portfolio of games. Microsoft's Game Pass launched in 2017—it's like Netflix, but for games. For between $5 - $15 per month, subscribers get access to hundreds of games, including hot new titles on the day of release.

## DISRUPTIVE IMPACT

The same challenges streamers are facing will befall gaming companies in the very near future. Game fans don't have unlimited budgets, and they'll need to choose between subscription packages.

## EMERGING PLAYERS

- Microsoft's Game Pass
- Google Stadia
- PlayStation Now
- Apple Arcade



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2ND YEAR ON THE LIST

# Infinite Gameplay

Fortnight launched in 2017 and quickly became one of the world's most popular games.

## KEY INSIGHT

**The most popular video games today have one thing in common: they never end. Rather than traditional games with a beginning, middle and end, many of these video games are more like online worlds, where players can participate whenever and for however long they like, with success measured in achievements instead of a single, finite objective.**

## EXAMPLES

Infinite gameplay means you never have to log off, and you'll never defeat the final boss. In these never-ending games, players can also take part in hybrid real-world experiences like going to a concert or even buying real estate. The Sims and Minecraft are examples of longstanding games that allow players to build their own realities. More recent titles like Fortnight and League of Legends are universes that players can log into at any time for a fully immersive and interactive break from the real world. Classic games like Super Mario, Pokemon and Grand Theft Auto are being redesigned and re-released in this unrestricted format to the delight of gamers everywhere.

## DISRUPTIVE IMPACT

How do you "win" a game if it has no end? Newer game design elements perfect addiction triggers and dopamine rewards to shape and alter our psychological state and behavior. Our lives will be increasingly gamified, as never-ending games merge with the activities that already form part of our lives. Connected exercise platforms, such as Peloton bikes, use built-in game elements (badges, contests and leaderboards). Meditation apps like Headspace nudge and reward us (somewhat paradoxically) to engage with them. Workplace optimization tools also encourage us to strive for new achievements, with progress and rewards being symbolized in digital form.

## EMERGING PLAYERS

- EVE Online
- Roblox
- Fortnight
- League of Legends
- Minecraft
- Twitch



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2ND YEAR ON THE LIST

# Sports Tech

Riddell's InSite training helmet collects and analyzes on-field head impacts.

## KEY INSIGHT

**Elite athletes are using more and more sophisticated tech tools to improve training and performance. Stadiums now use audience analysis and drones to improve the live and televised experience. Much of this sport technology could eventually end up in the hands of consumers looking to improve their health and well-being.**

## EXAMPLES

Professional NFL players are retiring early, citing a history of concussions and the risks of chronic traumatic encephalopathy, or CTE. Last year, seven-time Pro Bowl linebacker Luke Kuechly retired from the NFL at just 28 years old, and he wasn't the first to hang up his helmet before 30—quarterback Andrew Luck retired in 2019 at age 29. As competitive sports become more intense, data-tracking tools could help prevent the kinds of injuries that have led to these early retirements. Football equipment manufacturer Riddell now makes smart helmets outfitted with tiny sensors that transmit impact data in real time. Coaches on the sidelines can see the effects of single and multiple impacts sustained during a game, and they receive alerts if the numbers get too high.

## DISRUPTIVE IMPACT

Smart equipment is being developed for nearly every sport. The Wilson X Connected basketball is embedded with sensors and tracks patterns in shooting. Adidas makes a smart soccer ball with integrated sensors that can detect speed, spin, strike, and trajectory when the ball is kicked. Meanwhile stadiums employ drones and video for everything from audience sentiment analysis to cleaning up garbage after games. Italian equipment manufacturer Technogym is developing next-generation machines that incorporate a user's biometric data, which can be tracked before, during and after exercise. Emerging research in reduced-gravity activity is helping athletes re-acclimate after injury. AlterG's anti-gravity treadmill automatically reduces the natural weight of athletes to as little as 20% of body weight in precise 1% increments for low-impact, pain-free movement. Smart sports equipment could reach a market size of $12 billion over the next five years. The use of advanced technology in both analytics and performance is likely to alter the state of many contemporary sports.

## EMERGING PLAYERS

- AlterG
- Babolat
- Puma
- Riddell
- Technogym
- Under Armour
- Wilson



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2ND YEAR ON THE LIST

# Connected Toys

Sony's connected toy dog Aibo doubles as a smart home assistant.

## KEY INSIGHT

**Connected toys collect and use data for interactive experiences. While they're fun for kids, lawmakers and academic researchers have raised questions about privacy.**

## EXAMPLES

Thirty-six years ago, animatronic Teddy Ruxpin bears sang, told stories and even blinked. Priced at $69.99 (roughly $175.54 in 2021 dollars), the dolls had audio cassette decks built into their backs; specially-formatted tapes controlled the servo motors for Teddy's eyes and mouth, and also played audio recordings. For about the same price today, Cozmo is a small, self-aware, A.I.-powered robot with a base personality, and the more you play with him, the more that personality evolves. Made by San Francisco-based company Anki, the toy expresses anger when he loses a contest, and his eyes turn into upside-down U's to show joy. Facial recognition allows it to remember faces and call people by their names. Sony's Aibo is a lifelike robotic dog that responds to touch—scratch his neck and his tail will start wagging. You can teach him tricks, like fetching a ball and giving a high-five. Aibo also recognizes his owners using computer vision technology.

## DISRUPTIVE IMPACT

The upcoming generation of connected toys will use more data and will include even more personalization. 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 will instead connect to the cloud. This means increased bandwidth needs—and, very likely, new privacy concerns. In the U.S., 92% of children now have an online presence by the time they are 2 years old, according to AVG. Tech companies and toy manufacturers are still learning how to balance childrens' privacy, which is required under the Children's Online Privacy Protection Act (COPPA), with play.

## EMERGING PLAYERS

- Bandai Namco Holdings
- AWS
- Sony
- Wonder Workshop



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2ND YEAR ON THE LIST

# Kids Fitness Games and Toys

Nintendo's Ring Fit Adventure teaches kids how to do basic exercises.

## KEY INSIGHT

**Parents, increasingly concerned that their children aren't getting enough exercise, are looking to toys and games that nudge kids into more active lifestyles. They're also borrowing from the quantified-self movement to monitor kids' health and wellness.**

## EXAMPLES

Approximately one in three children in the U.S. are now considered to be overweight or obese, according to the U.S. Centers for Disease Control and Prevention. Researchers point to a lack of physical activity as a contributing factor. As a result, games and toys that encourage healthy behaviors are an attractive market for toy developers, fitness trackers and game designers. The Gululu interactive smart water bottle and health tracker for kids encourages them to drink more water. The bottle includes an LED screen with a preloaded game. The more water kids drink, the further their character will get in the game. Parents can monitor their children's hydration in real-time using a mobile app.

## DISRUPTIVE IMPACT

Nintendo's Ring Fit Adventure is a connected fitness add-on for the Nintendo Switch console. The game takes the player on an athletic adventure through worlds, villages and gyms. Cute monsters, dispatched by arch-nemesis Drageaux, challenge players to battles: simple yoga poses, squats, crunches and planks. During the quest, players jog or run in place. Kids who play the game spend an average of 30 minutes in active movement. On the horizon: massively multiplayer online fitness games, in which kids can connect with each other and go on active adventures together.

## EMERGING PLAYERS

- Bandai Namco Holdings
- Garmin
- Nintendo



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1ST YEAR ON THE LIST

# Protecting Little Gamers

Parents and privacy advocates are increasingly concerned about the data being collected as 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 set up, 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



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3RD YEAR ON THE LIST

# Digital Addiction

Digital addiction affects children as young as 2 years old.

## KEY INSIGHT

**Digital products rely on habit-forming features for success, but a growing body of research highlights the negative impacts that those sticky features can have on mental health and well-being.**

## EXAMPLES

The World Health Organization added gaming disorder to the next edition of the International Classification of Diseases in May 2019, making it one of the few behavioral health addictions to gain formal recognition. In the tech realm, companies are responding with design changes to reinforce healthy device use. Instagram experimented with removing public like counts to discourage users from comparing themselves to others. Several startups are pursuing mini-smartphones designed with smaller screens and stripped down interfaces to encourage users to look at their devices less often. Google and Apple continue to develop features that help users monitor their digital well-being and screen time.

## DISRUPTIVE IMPACT

As concern about digital addiction increases, consumers will become less tolerant of so-called "dark patterns" that use psychological cues to induce greater consumption. Every business model for media hinges on commanding the attention of an audience. As social attitudes toward technology shift, product designers should be mindful that they're not perceived as eliciting detrimental behavior or harming the physical and mental health of their users.

## EMERGING PLAYERS

- Center for Humane Technology
- Twitch
- TikTok
- Snap
- World Health Organization



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## Digital Drugs

**Mid-future pessimistic scenario**

There is more than one way to alter your state of mind when perception-altering technologies are the norm. We use biohacking to give ourselves an excessive rush of dopamine, we use diminished reality for sensory deprivation induced hallucinations, and we use dissolving bioelectronics as a stimulant. Party-goers test their limits. Researchers rush to find antidotes for those that trigger psychosis, loss of neural functions, and permanent brain damage. Digital addiction takes on a whole new meaning. A prolonged dose of reality is the only prescription.

# Scenarios



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# Application

## STRATEGY

Covid-19 forced many companies to recalibrate their strategies, or postpone their annual planning cycles. This had a dramatic acceleration on digital transformation efforts, which in some companies had only just begun. Even before the world reopens and employees are vaccinated, chief strategy officers must make critical decisions about whether to champion a distributed workforce or to recentralize operations. Strategy executives should find a balance between near and long-term upskilling, operations, and technology implementation.

## INNOVATION

The intersection of work, culture and play unlock tremendous opportunities for innovation teams. From new product development, to experimentation in distributed office structures, to completely reimagining fashion, games, beauty and toys, creative risk takers are in a position to shape the future of their industries. Chief innovation officers should lean in to all this disruption and champion thinking across longer-term time horizons within their organizations.

## R & D

In the realm of digital vices, R&D teams have plenty to investigate. The future of work will continue to take shape over the next few years. For example, what might a decentralized office look like in five years? What will the infrastructure and technology needs be? When it comes to neuroenhancers and CBD, investors are enthusiastic about the possibilities. Rather than waiting to see what regulations pass, R&D teams can begin preliminary research on questions and hypotheses that could deliver stronger business outcomes in the future.

## RISK

Chief risk management officers found that their typical risk profiles shifted in the past year, and not all companies were prepared. Strategy will be more agile and dynamic going forward, especially as work, play and culture intertwine. With work from home policies in flux, widely available enhancers and vices, and an endless stream of digital distractions, an organization's ability to manage risk this year could be a vulnerability. Or a strategic differentiator.



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# 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 tracking disruptions outside of our immediate industry?

Which trends require a deeper understanding?

2

With regard to digital vices, what is our position on transparency, ethics, and accountability?

Do our employees understand this position? Do our customers?

3

Will our organization benefit from continued remote work?

How can we reimagine our physical and digital workspaces?



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Volume 5 of 12

14th Annual Edition

# 2021 Tech Trends Report

Strategic trends that will influence business, government, education, media and society in the coming year.

- Health
- Medical
- Wearables

Future Today Institute

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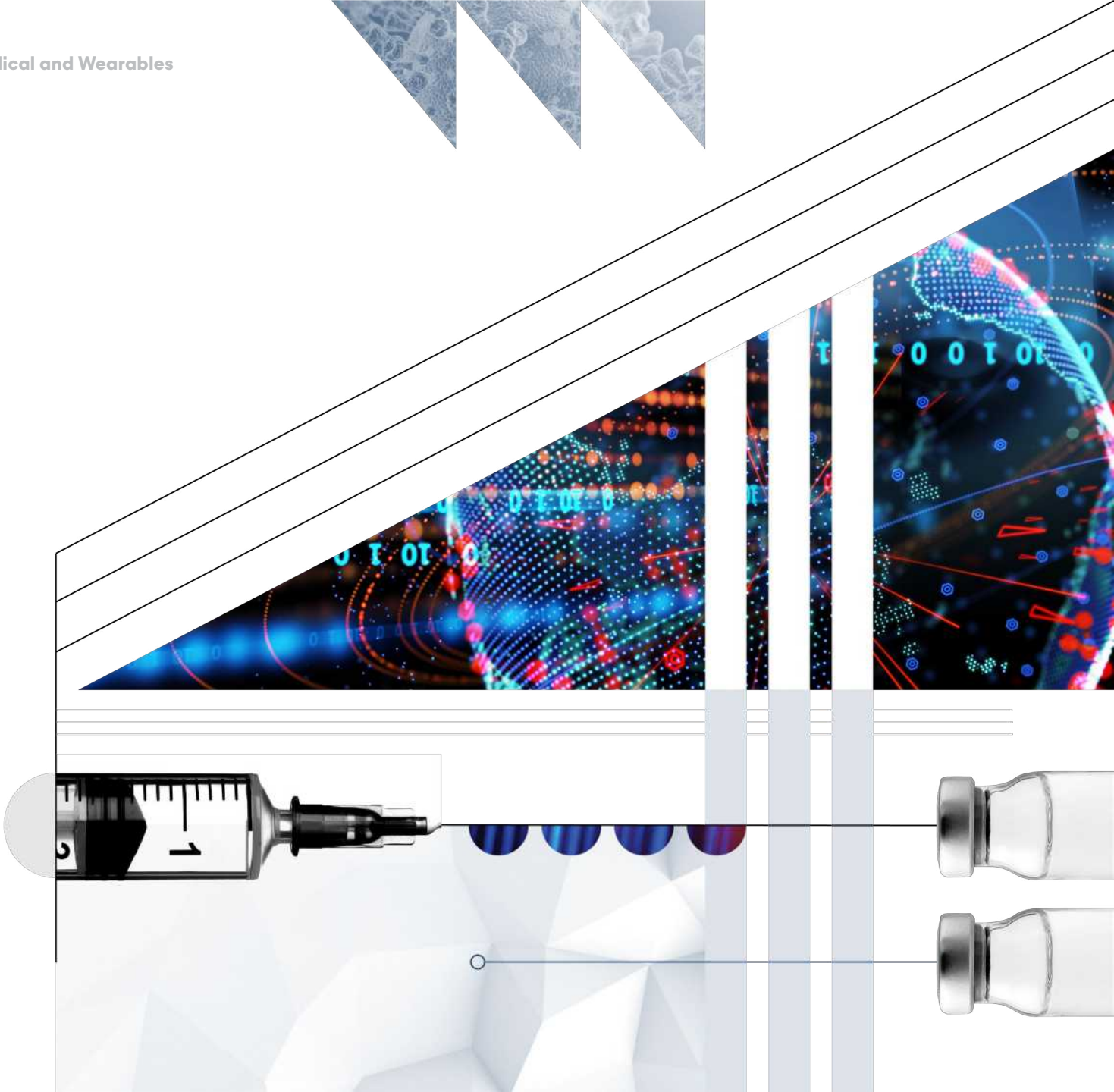

# Health Medical Wearables Summary

- Health care is the next battleground for big tech companies. Amazon, Google, Apple, and Facebook see health care as ripe for disruption—and an industry where they can make positive improvements.
- Because of its scale and reach, Amazon could force established pharmaceutical companies, health care systems, and insurers to adapt and evolve.
- COVID-19 accelerated the adoption of telemedicine visits, which spurred a new digital transformation effort in health care.
- More diagnostic tests are being done at home using connected devices, including smart mirrors and smart toilets.
- Last year was a sudden dress rehearsal for widespread remote patient monitoring.
- The last few years saw the launch of smart fitness equipment, which includes mirrors, bikes, and treadmills. The pandemic accelerated sales and helped the market grow significantly.
- Video games are being developed to treat certain conditions and diseases. Prescription-strength games even carry Food and Drug Administration approval.
- Sleep tech is big business: By 2026, the market size could be upward of $30 billion.
- This could be the year that Facebook and Apple launch their smart glasses.



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1ST YEAR ON THE LIST

# Doctorless Exams

AliveCor's personal EKG monitoring system.

## KEY INSIGHT

**Advancements in diagnostic testing and remote monitoring, supported by cloud computing, machine learning, and low-cost technology, are upending traditional doctor visits. Patient data is triaged by algorithm, rather than human doctors alone.**

## EXAMPLES

Smartphones and smartwatches now take blood pressure readings and perform electrocardiograms, using apps approved by the Food and Drug Administration. Phones don't just record data; they interpret it. People who wear an Apple Watch know that an unusually high or low heart rate or irregular rhythm may suggest atrial fibrillation. The VROR system, a VR-based eye exam, emulates an eye doctor's ultra-widefield imaging machine but within a compact headset. Data is sent to a mobile app for an understanding of a patient's optic nerve health. Steth IO is a mobile stethoscope that uses a smartphone to capture, decode, and analyze heart sounds. AliveCor is an FDA-cleared wireless personal EKG that connects to a phone. Butterfly iQ is a portable ultrasound device that delivers a 2D image. The ParatusPerio Test analyzes different bacteria and sources of inflammation in a patient's mouth.

## DISRUPTIVE IMPACT

Continual monitoring helps patients know their baseline vital stats and track any changes. This disrupts traditional health care in a few ways. First, with continual monitoring, patients are more likely to intercept an emerging problem in advance and seek out care. For example, some patients will call their doctor for next steps if their smartwatch warns of atrial fibrillation. This reduces strain on emergency departments. It also unlocks new opportunities for health care systems and insurers willing to use such data and to make medical records systems interoperable. Financial forecasting that harnesses real-time data could be algorithmically recalibrated and more accurately assess risk. But connected devices aren't accessible to everyone, which means a new digital divide could be on the horizon, further reducing health equity in many communities.

## EMERGING PLAYERS

- The Clue period tracking app
- Apple Health
- Steth IO
- Healthy.io
- Paratus Diagnostics
- Butterfly Network
- AliveCor



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1ST YEAR ON THE LIST

# At-Home Medical Laboratory Tests

The Toto Wellness Toilet can analyze your waste.

## KEY INSIGHT

**The everyday equipment in your bathroom will soon be used to collect biological samples for daily monitoring and testing. You won't have to worry about making appointments to visit a diagnostic lab—and then wait in lines and wait even longer for results—as a new crop of technologies intends to conduct scans at home.**

## EXAMPLES

Because toilets are in direct contact with two key sources of data—our skin and our waste—they offer opportunities to analyze our real-time health. Stanford University researchers identified different cancers, liver diseases, and gut disorders using motion and pressure sensors, urinalysis strips, computer vision, and infrared sensors. Toto's new Wellness Toilet builds on that research by using sensors to analyze "key outputs" and give users insights on hydration and their diets. Kohler's smart toilet uses Amazon Alexa voice controls. Healthy.io's Velieve, a urinary tract infection test kit, uses a mobile app to connect patients who have positive results with an online doctor and sends a prescription to a nearby pharmacy if needed. Healthy.io also partnered with the National Kidney Foundation to offer an annual kidney test kit to detect early disease.

## DISRUPTIVE IMPACT

COVID-19 accelerated the use of telemedicine in the U.S. and other countries where remote visits were previously restricted. With telemedicine as a new normal, at-home lab tests will increase and disrupt diagnostic companies, such as Labcorp and Quest Diagnostics, and drugstore retailers with clinics, such as Target and CVS.

## EMERGING PLAYERS

- Healthy.io
- Toto
- Everlywell
- Imaware
- FoodMarble
- Lumen
- LetsGetChecked



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1ST YEAR ON THE LIST

# Telemedicine

A young family consults with their doctor using a telemedicine app.

## KEY INSIGHT

**Telemedicine isn't a new concept. The technology for facilitating and encrypting video consults has been available for years, but it represented a paradigm shift in the traditional doctor visit. COVID-19 forced an overnight change as lockdowns prevented health care providers from seeing patients except in cases of emergency.**

## EXAMPLES

Telemedicine had previously been offered only to people in difficult-to-reach locations, such as sparsely populated rural areas or the International Space Station. Medicare restrictions limited remote visits to patients who met certain criteria or forced them to travel to approved centers for the video meetings. But telemedicine has since flourished. A study by nonprofit group FAIR Health showed a 4,347% surge in telemedicine claims in the U.S. between March 2019 and March 2020. The Centers for Medicare and Medicaid Services also added 80 more services to be delivered remotely and now allow providers to bill at the same rate as in-person visits. Artificial intelligence is part of telehealth's evolution. Recognition technologies for voice, emotion, gesture, posture, and more can add to a doctor's evaluation of a patient. AI can already detect whether someone has a cold or is despondent, relative to their normal disposition.

## DISRUPTIVE IMPACT

Telemedicine unlocks new opportunities for growth, not to mention easier access to health care and a chance to improve health equity. For example, telemedicine can address the rising challenges of provider workloads, hospital or clinic space, and labor-intensive data entry. Remote visits reduce strain on facilities, while adjacent technologies (automated medical transcription, fitness and health monitoring apps and wearables, at-home diagnostic tests) and machine learning can optimize the speed and scope of data collection. Clinics and hospitals can scale treatment without adding new staff resources and reduce hospital readmission rates by remotely coordinating with home care providers.

## EMERGING PLAYERS

- Eko
- Aluna
- Biofourmis
- Current Health
- Myia Health
- Olive
- Notable Health
- Alpha Health
- Qventus
- Augmedix
- Suki
- CloudMedx
- Corti
- Butterfly Network
- Arterys



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## A New Kind of Body Shop

**Mid-future neutral scenario**

Implanting technology in the human body for various aesthetic and functional purposes has entered the mainstream as a popular new form of self-expression. Tech-focused body modification—called grinding when performed DIY—emerges as a new market situated somewhere between the decorative piercing industry and the medical field. A new type of establishment begins to appear in major cities to serve this subculture, a hybrid of a walk-in neighborhood clinic and a tattoo shop. These body shops have retail storefronts, but with enough equipment, trained staff, and permits to allow them to perform minimally invasive surgeries. The most popular requests for implants? Magnets, RFID chips, glow-in-the-dark shapes, and wireless data storage. Sounds pretty cool, until you walk through your next metal detector.

# Scenarios



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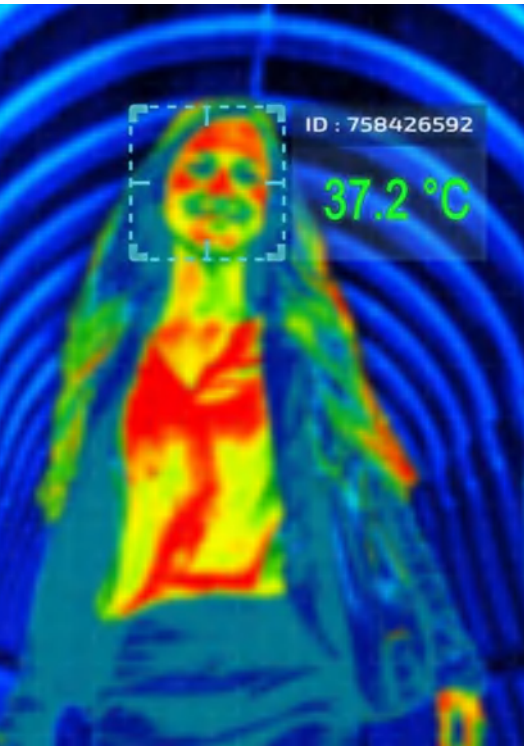
1ST YEAR ON THE LIST

# Biometric Screening Systems




New biometric screening systems use thermal imaging to check temperatures.

## KEY INSIGHT

**In the wake of COVID-19, schools, offices, and even homeowners began using biometric scanning systems to determine whether someone is sick—and to grant or deny them entry.**

## EXAMPLES

Office buildings, grocery stores, movie theaters, and health care facilities now use temperature checks to screen for COVID-19 symptoms, based on guidance from the Centers for Disease Control and Prevention. This year, Plott will introduce the Ettie, a $300 video doorbell system that performs an automatic temperature check and displays it back to the user. An LED panel will glow red if a visitor has a fever, and the system will refuse her entry. Ettie can also be programmed to limit the capacity of entrants; when capacity is hit, the door will not unlock (even if that person has been temperature-cleared). FLIR Systems, an infrared camera maker, sells FDA-certified cameras that can check workers in 10 seconds or less and focuses on tear ducts, which tend to give a truer reading of someone's body temperature than the forehead, which can be warmed by hats, hoods, and direct sunlight.

## DISRUPTIVE IMPACT

Biometric screening systems run up against paradoxical regulations in the U.S. While the Health Insurance Portability and Accountability Act (HIPAA) requires companies to develop and follow procedures that ensure the confidentiality and security of protected health information—meaning that workers would need to consent to be scanned—customers and other members of the public are not covered under HIPAA (unless the owner of the camera is a health care provider). It's not clear whether infrared doorbells on private homes would be allowed under California's Consumer Privacy Act. Laws in Illinois, Texas, and Washington now regulate the collection of biometric data, including body scans.

## EMERGING PLAYERS

- Plott
- FLIR Systems
- Electronic Frontier Foundation
- Thermoteknix Systems
- Opgal
- Mobotix
- Dahua Technology



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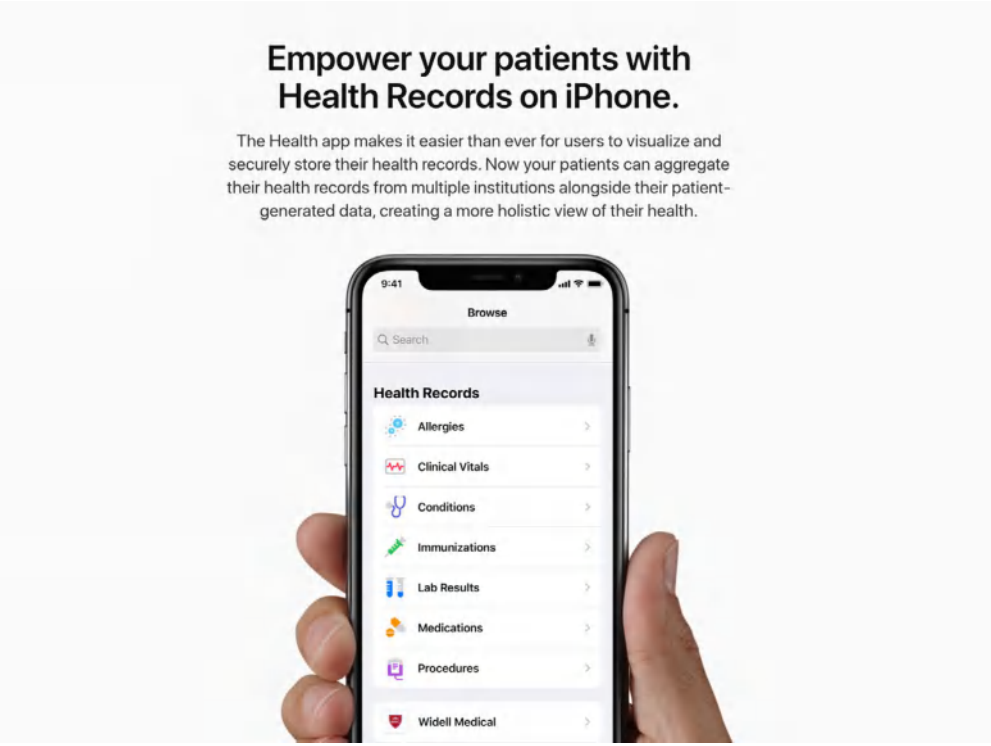
3RD YEAR ON THE LIST

# Big Tech Disrupts Health Care




Apple's Health Records offers an alternative to traditional electronic health records. systems.

## KEY INSIGHT

**Health care is the next battleground for big tech companies. Amazon, Google, Apple, and Facebook see health care as ripe for disruption—and an industry where they can make positive improvements.**

## EXAMPLES

Data scraped from Fitbit devices—steps taken, heart rate, hours of sleep, and other key metrics—lets Google make recommendations and optimize consumer habits. It also opens a giant pool of data for research. Google and Ascension, one of the largest health care systems in the U.S., will build a robust search tool to aggregate patient data—lab results, hospitalization records, vital statistics—and house it under one system. The Apple Watch Series 4 doubles as a medical device, able to detect when someone has a hard fall and to call 911; identify a dangerous heart rhythm condition called atrial fibrillation; and track menstrual cycles, heart rate, and overall mobility. Apple's Health Records, launched in 2018, pulls data from other Apple products to help patients and providers see comprehensive data—medications, lab results, immunizations—in one spot. Meanwhile, AC Wellness, a subsidiary of Apple and a clinic for Apple employees, started offering free genetic screening in 2019. Facebook's Preventive Health tool lets users set reminders for health screenings and find nearby providers.



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# Big Tech Disrupts Health Care continued

Amazon is among the big tech companies disrupting traditional health care.

## DISRUPTIVE IMPACT

The world's largest tech companies are tackling the $3.6 trillion U.S. health care industry with initiatives spanning basic scientific research and health care application research, revamping insurance, creating new clinics, and melding our data with their interactive devices. Google is a world leader in applying AI to medical research—its automated breast cancer detection system already outperforms oncologists. Pre-pandemic, health and medicine inquiries made up 7% of all Google searches. Google's $2 billion Fitbit purchase should spur more health care innovation. Facebook's preventive health tool could influence health outcomes for users by relying on the social media company's standard notifications. Yet Amazon's plans are the most comprehensive of all tech companies—and potentially the most disruptive to the health care industry. *(See: Amazon's Health Care Ambitions.)*

## EMERGING PLAYERS

- Google Health VP Dr. David Feinberg
- Google Senior Fellow Dr. Jeff Dean
- Google Cloud
- Apple Chief Operating Officer Jeff Williams
- AC Wellness
- Facebook Head of Health Technology Dr. Freddy Abnousi



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# Amazon's Healthcare Ambitions

When Amazon acquired mail-order pharmacy PillPack in 2018, many thought it was just an extension of the company's logistics and delivery business. If consumers were already buying toilet paper at Amazon.com, why not blood pressure medication? Those who intentionally connected the dots between Amazon's different strategic initiatives saw a clearer, bolder picture of Amazon's health care ambitions—a massive disruption of health care was already underway.

In 2019, Amazon rebranded its acquisition as PillPack by Amazon Pharmacy, which launched in late 2020. Now patients can ask their doctors to send prescriptions directly to Amazon, which then ships medications to consumers. This signals interesting changes on the horizon. Because of its scale and reach, Amazon could force pharmaceutical manufacturers to lower drug costs, just as it pushed down the average prices of other product categories available on its retail site.

Zooming out, there are many other ways in which Amazon will (or has already begun to) disrupt the entire health care ecosystem, from drug development to insurance management. Here are just a few key areas of innovation:

## Data Analytics

Amazon Web Services (AWS) launched HealthLake, a health care analytics platform that is HIPAA-eligible and works to standardize unstructured clinical data for the cloud (solving a major pain point for providers). HealthLake will make it easier for Amazon to partner with more health care providers and build its health ecosystem.

## Drug Development

Partnering with Accenture and Merck, AWS created a cloud-based informatics research platform to improve productivity, efficiency, and innovation in the early stages of drug development.

## Telemedicine

Amazon Care, the company's telemedicine program, has been expanded to a broad range of employees beyond its Seattle-focused beginnings. Early pitches of the service to outside employers could start to upend the current provider and insurer market.

## Online Pharmacy

Amazon Pharmacy offers online prescription fulfillment and home delivery of medications via the Amazon website or mobile app. Amazon Prime members get free two-day delivery, of course. There are now 118 million Prime members in the U.S.—if even 10% move their prescriptions away from a traditional drugstore retailer (like a CVS, Walgreens, Rite Aid, or a local pharmacy), it could cause serious disruption to the $312 billion pharmacy and drugstore retailer market.

## Medical Transcription

Amazon Transcribe Medical is an automatic speech recognition service enabling providers to transcribe examinations and other medical commentary in real time.

## Senior Care

Last year, Amazon launched Care Hub, a tool to assist caregivers in senior home centers. One feature: If a senior says "Alexa, call for help," it will automatically ping the caregiver.

## Personal Diagnostics

Alexa now recognizes changes in individual voices, by detecting emotional states and other factors, such as whether someone has a stuffy nose. Last year, Amazon launched Halo, its data-hungry health monitoring wristband. Halo measures body fat percentage, listens to the user's emotional state, and monitors heart rate and other activity. One of the largest electronic medical record companies, Cerner, said that Halo users will have the option to upload information collected by the device to their physicians' Cerner health record, beginning with the Sharp HealthCare system in San Diego. Insurer John Hancock is partnering with Amazon to offer members a free Halo and three-year membership in exchange for data.

## Grocery Stores

At Amazon Go grocery stores, shoppers select foods and pay using gestures or other biometric recognition. Shopping data is stored and can be correlated with other health data. Quantifying how many bags of chips bought in a year—versus how many apples—could be an interesting data point on a future personal health record.

## Bottom Line

As Amazon continues to prioritize customers and their experiences, it poses an additional threat to traditional health care providers. In the U.S., customer service throughout the health care value chain—scheduling appointments, getting lab results, standardizing medical records, billing, insurance—is notoriously bad. Amazon stands to cut out middlemen that drive up health care costs. It could transform the cadence of work, by creating instant medical records and offering immediate diagnostic results.

For those who point to the dissolution of Haven, Amazon's joint venture with Berkshire Hathaway and JP Morgan Chase, as a sign of trouble, note that the collaboration resulted in Amazon making tremendous progress on its own Amazon Care program.



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## These Walls Can Talk

### Mid-future pessimistic scenario

When affordable smart home ecosystems first hit the market, the appeal was clear: For a reasonable price, you can equip most devices and systems in your home to anticipate and accommodate your preferences, and carry out your wishes in response to voice commands. But after households grew to rely on these smart home technologies, they noticed their average yearly medical expenses began to rise. As with much modern tech, if you're not paying much in dollars, you're probably paying in data. What had been marketed as domestic convenience turned out to be a 24-hour monitoring system. Data about every family member's movements was captured and sold to insurers and care providers, who used it to justify penalties and rate hikes. A cigarette on the porch after the kids are in bed? Your deductible just went up, as did your monthly life insurance payment. Lifting the couch to vacuum underneath? You just voided your prescription for pain meds to treat last year's back injury. Order a side of cheesy fries with your dinner delivery? Coverage of conditions related to obesity and heart disease now comes at a premium. The whole setup brings new meaning to the question, "Is there a doctor in the house?"

Scenarios



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1ST YEAR ON THE LIST

# Chief Health Officers

In January, Delta Air Lines hired its first chief health officer, Dr. Henry Ting, a medical leader with deep and broad experience in patient care, medical research, education, and management.

## KEY INSIGHT

**Health is the state of wellness—it's the opposite of sickness. Companies are beginning to add chief health officers to the C-suite, to direct strategy for employee wellness and consumer health. Previously, CHOs (as well as chief medical officers) were limited to pharmaceutical companies, hospitals, medical systems, and insurance companies.**

## EXAMPLES

In January, Delta Air Lines hired its first chief health officer, Dr. Henry Ting. He joined Delta from Mayo Clinic and will now focus on health and well-being, safety, data strategies, and health-related partnerships for the airline. Colleges and universities are adding CHOs to their executive cabinets to develop policies and strategies that promote health and wellness to students, faculty, and staff—in the past two years, Bowling Green State University and the University of Michigan have hired CHOs. The position is also included in the org charts of IBM, Apple, Amazon, and Google.

## DISRUPTIVE IMPACT

COVID-19 accelerated the visibility of CHOs. Royal Caribbean Group and Viking River Cruises hired their first CHOs last year, which makes sense: The cruise industry struggled to maintain health and safety in the wake of the virus. Beyond the pandemic, CHOs are looking holistically at employee and customer wellness. If people are healthy and safe, then they're more productive—and as consumers, potentially willing to spend more on products and services.

## EMERGING PLAYERS

- Association of State and Territorial Health Officials
- Johns Hopkins Center for Health Security
- Johns Hopkins Bloomberg School of Public Health
- Amazon Halo



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1ST YEAR ON THE LIST

# High-Tech Concierge Care

Forward is a concierge care system focused on high-tech, evidence-based medicine.

## KEY INSIGHT

**Concierge care services have gone high tech. Medical providers are upgrading their membership models, which combine medical care with tech-first wellness, personal data, and luxury hospitality.**

## EXAMPLES

Forward is a preventive health care membership that relies on advanced technologies to diagnose and treat patients. Visits include biometric body scanning, a blood panel, genetic analysis, skin screening, and a mental health assessment. Patients then download an app, which is continuously connected to wearables, medical devices, and medical records aggregated from previous caregivers. The Lanby, a medical and wellness club, is slated to open in New York City in fall 2021. For $3,500 annually, members get a baseline assessment with a full physical and labs, a personal care plan, and monthly checkups, using telemedicine. These clubs could administer certain exams and treatments in an ultra-modern medi-spa ambience rather than that of a clinic.

## DISRUPTIVE IMPACT

Concierge medical practices first opened in the U.S. in the 1990s, and doctors commanded annual fees of $10,000–$50,000 (and sometimes more) for 24/7 access to care. Fees were out of reach for most, and this model incentivized slow, personalized, ongoing care rather than the fast, efficient visits only during times of need, which insurers prefer. A concierge doctor could therefore maintain his existing salary by managing far fewer patients.

This next generation of concierge care relies on home diagnostics, self-monitoring, and telemedicine, and that will allow providers to scale back up again to service a large patient base and further threaten the traditional business model for health care.

## EMERGING PLAYERS

- The Lanby
- Forward
- Tia
- Higi
- mPort



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1ST YEAR ON THE LIST

# Remote Patient Monitoring

The Zio patch allows doctors to remotely monitor patients.

## KEY INSIGHT

**Last year was a sudden dress rehearsal for widespread remote patient monitoring (RPM). Due to COVID-19 lockdowns, the market for RPM technologies flourished, while hospitals and health systems launched new ways of collecting data and billing patients.**

## EXAMPLES

The Cardea SOLO ECG System is a wearable heart monitor that sends data back to a monitoring center. Electrocardiogram data is analyzed and reports are generated within minutes to expedite a diagnosis and treatment if necessary. The Zio patch from iRhythm Technologies is a complete ambulatory cardiac monitoring solution.

## DISRUPTIVE IMPACT

RPM uses digital technologies, the internet, and the cloud to collect medical data from patients in one area and transmit it for assessment by providers working somewhere else. Lots of data—heart rate, electrocardiograms, blood pressure, blood oxygen levels, kidney function, and more—can be mined and used to manage cases off-site. RPM can keep older people out of nursing homes and reduce the number of in-person visits to clinics and hospitals. As the number of chronic health conditions rises, RPM will gain a stronger foothold in health care.

## EMERGING PLAYERS

- VitalConnect
- Ascom
- G Medical Innovations
- Gyant
- Huma
- Ejenta
- CardiMo
- Cardiac Insight
- Rhythm Technologies
- 100Plus
- Neteera



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1ST YEAR ON THE LIST

# Digital Transformation in Health Care

Health care has lagged behind in digital transformation, but that is changing.

## KEY INSIGHT

**When it comes to digital transformation, health care has lagged behind most every major industry, including retail, banking, consumer packaged goods, and even government. Roughly 70% of U.S. hospitals still rely on fax machines to move patient records around. That makes the industry ripe for disruption—and attractive to startups and investors alike.**

## EXAMPLES

Investors poured $8.4 billion into global health funding in just the third quarter of 2020 alone— much of those dollars were aimed at helping health care providers cross the digital transom, according to research firm CB Insights. Mayo Clinic and Medically Home will provide hospital-level care to patients' bedrooms, performing lab tests, infusions, and remote monitoring while processing all of the needed data for patient and hospital records, insurers, and government agencies. Epic, one of the largest U.S. medical records system providers, will make its data more accessible from business to business. Its partnership with Nuance Communications' voice recognition software platform will allow doctors to send dictated notes to other medical specialists. It's also experimenting with ride hailing company Lyft to bring patients to hospitals.

## DISRUPTIVE IMPACT

There is a push for standardized, open data in health care, and the largest providers are starting to see the value of making their data interoperable. Dedicated cloud services, standardization of data, robust electronic medical records systems, encryption, and a host of medical-grade consumer devices are forcing the notoriously stodgy industry to evolve and adapt to the modern realities of technology. Medicine's regulatory minefield has so far prevented investment outside of a narrow field of innovations. That's all starting to change, in part because of the big technology companies endeavoring to disrupt the business.

## EMERGING PLAYERS

- General Catalyst
- Geisinger
- Epic
- Accenture
- Alibaba's AliHealth
- Qualcomm
- Nokia



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3RD YEAR ON THE LIST

# Patient-Generated Health Data

VALIDIC

Validic uses mobile health APIs to access data from a host of devices and apps and make it usable with a patient's EHR.

## KEY INSIGHT

**Patients are creating a trove of data that could contribute to their health care provider's overall health assessment. Packaging all that data—and figuring out how to make use of it—is still a challenge.**

## EXAMPLES

From Google's Fitbit, to Apple's Watches and AirPods, to household smart scales, hundreds of devices can now collect and monitor patients' health. We also generate data at the doctor's office, and under federal law, that data must be filed and stored electronically. The problem is in aggregation. Because the data is structured differently, an intermediary is needed to make practical use of it. The result: a new market for businesses that can clean, structure, and package patient-generated health data. Software from companies like Validic allows doctors to collect this type of data and incorporate it into their medical records. This software uses mobile health APIs to access data from devices and apps and incorporate it with a patient's electronic health record (EHR). GE Healthcare, Meditech, Allscripts, eClinicalWorks, and Cerner are all building products to make better use of our data.

## DISRUPTIVE IMPACT

Safely moving, storing, and making use of this data will require encryption. But there is also value in taking a fuller view at the community, state, or even national level. Differential privacy measures will enable companies to anonymize a patient's details while still making their data useful to scientific researchers.

## EMERGING PLAYERS

- Validic
- Apple's Health Records
- Amazon Transcribe Medical
- Salesforce
- Google Health
- Meditech
- Allscripts
- eClinicalWorks
- Cerner



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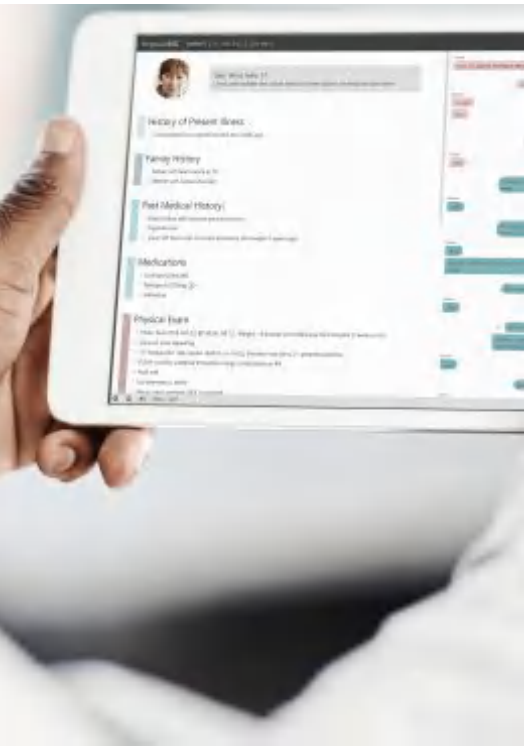
2ND YEAR ON THE LIST

# Automatic Medical Transcribing



Microsoft's EmpowerMD listens to clinical conversations between doctors and patients.

## KEY INSIGHT

**Dictating patient notes is a core task in a clinical practice. But transcribing recordings is a tedious process that relies on excellent sound quality and a good understanding of medical terminology—not to mention one that requires confidentiality. Artificial intelligence promises faster transcriptions as well as real-time diagnostic analysis.**

## EXAMPLES

Amazon's Transcribe Medical frees up doctors' time by transcribing doctor-patient interactions directly into an electronic record. Amazons Comprehend Medical helps developers use unstructured medical text for diagnostic tools, while AWS's software integrates into devices and apps using an API. Microsoft's Project EmpowerMD partnered with Nuance Communications to listen to conversations between doctors and patients and automatically integrate information from the patient's EHR in real-time. Built on Azure, it uses a rich set of machine learning algorithms to tackle natural language challenges and generate a medical summary. Meanwhile Google plans to leverage its speech recognition for medical conversations.

## DISRUPTIVE IMPACT

To meet compliance regulations, a strict protocol must be followed when a third party transcribes sensitive doctor-patient audio. But what if the transcription is performed in real time? Not only would it be easier and more cost-effective in building patient records, an additional layer of machine learning could help doctors learn more about their patients during each visit.

## EMERGING PLAYERS

- AWS's Amazon Transcribe Medical and Amazon Comprehend Medical
- Nuance Communications
- Microsoft Azure's Project EmpowerMD
- IBM Watson's Speech to Text



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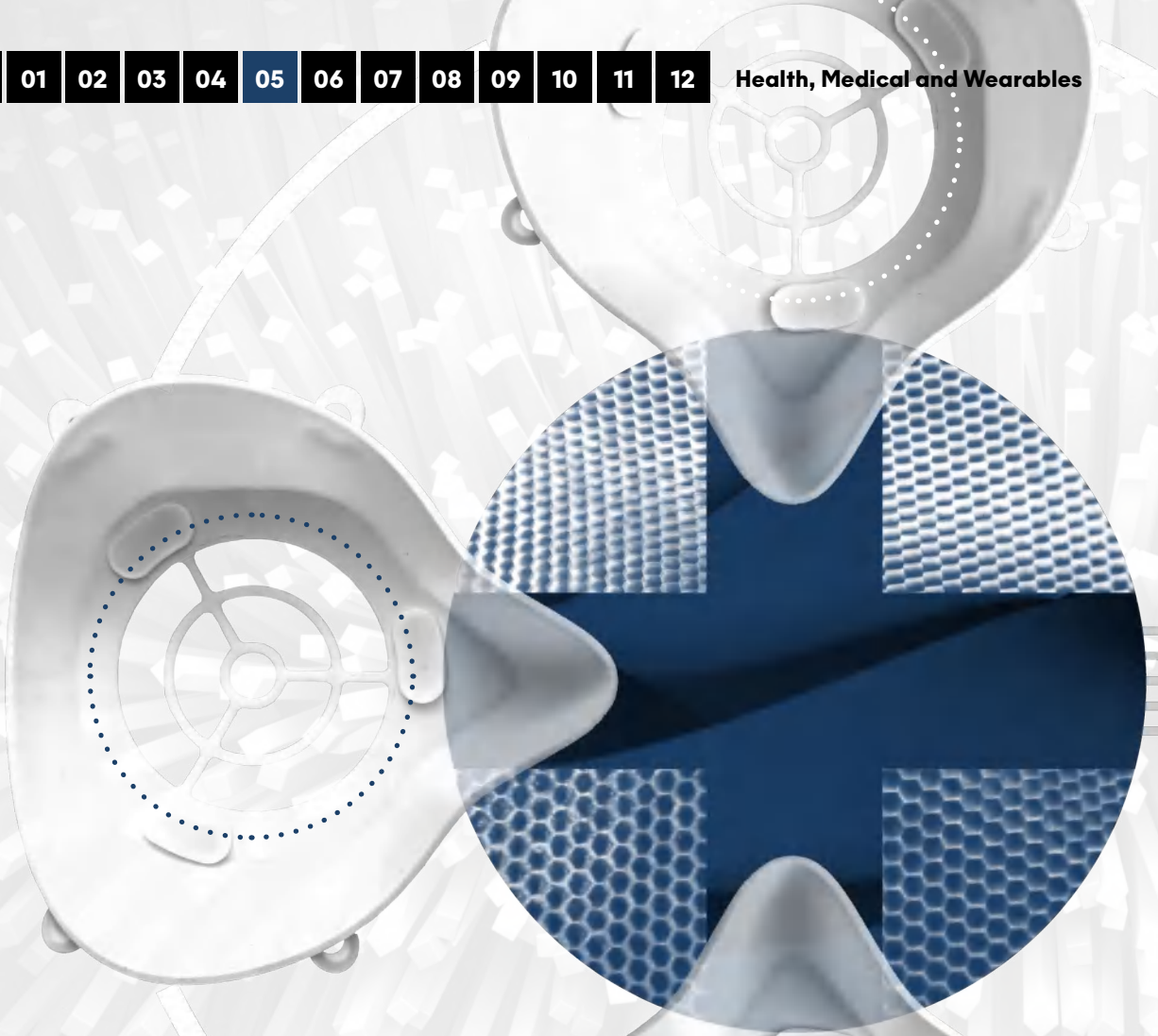

## 3D Printing in the ER

**Near-future optimistic scenario**

Hospitals across the country embrace 3D and 4D printing. In partnership with medical product designers, 3D printing technicians become critical to care ecosystems, particularly in the emergency room. Rather than storing a fixed inventory of equipment, hospitals use additive manufacturing to produce items on demand ranging from personal protective equipment and ventilator components to stents and custom braces, and then break them down or sterilize and recycle them when they're no longer needed. It's all about efficiency, personalization, and real-time response to the emergencies that come through the doors. Ambulances and mobile hospitals are equipped with printers, too, so that they can treat patients during transport.

# Scenarios



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1ST YEAR ON THE LIST

# Smart Biohazard Wearables

Production Club's Micrashell is a smart biohazard wearable designed for clubbing.

## KEY INSIGHT

**At the height of the COVID-19 pandemic, many people went in search of high-quality masks that would prevent viral transmission and also collect air quality data. But given the uptick in dangerous air quality due to wildfires and pollution, smart biohazard wearables are attracting more attention.**

## EXAMPLES

The AirPop face mask protects against environmental and biological contaminants. A sensor embedded in the mask connects with a mobile app to analyze the general air quality; it also displays the pollutants blocked, whether or not the filter needs to be cleaned, and personal breathing metrics. Razer's Project Hazel is a surgical N95-grade mask with a clear face panel design, a microphone to help project your voice, and UV light disinfection that promises to kill bacteria. The Atmoblue, which launched as an IndieGogo project and raised 10 times its initial funding goal, includes a smart, wearable air purifier with HEPA filters and dual, high-speed centrifugal fans.

## DISRUPTIVE IMPACT

Between worsening environmental pollution and the worldwide spread of an airborne pathogen, the consumer demand for medical-grade protection from biohazards has grown significantly. Expect an influx of investment in response to that demand, with a focus on additional protective functionality, added data-capture tech, certification from medical institutions, and potential partnerships to equip at-risk workforces.

## EMERGING PLAYERS

- Razer
- AirPop
- Atmoblue
- Production Club



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1ST YEAR ON THE LIST

# Cognitive and Neural Optimization

Bitbrain's headsets optimize neural activity.

KEY INSIGHT

**Most cognitive training programs are nothing more than clever memory games, but a new crop of technologies promises to optimize neural function. People who engage in this form of training report feeling quicker, sharper, and more capable of sensing, parsing, and acting on information.**

EXAMPLES

One key element of this trend is neuroplasticity, or how well the brain adapts and toggles speed and accuracy with the information it receives. Plasticity-based challenges form new neural pathways in the brain, which can be later called upon to process a greater range of stimuli. Reflexion promises to help people train for speed and accuracy in competition, which is why college athletic departments and researchers at Pennsylvania State University, Duke University, and the U.S. Air Force Academy all use the platform. The cloud-based system has a 55-inch touchscreen light board that comes with a series of visual exercise drills and analytics to track and strengthen brain fitness. It measures peripheral vision, decision-making, reaction time, and hand-eye coordination.

Halo Neuroscience makes a brain-stimulating headband for "neuropriming," using electrical stimulation to increase plasticity in the brain prior to an activity. The headband transmits weak electrical pulses into the user's brain with the intent of enhancing the efficiency of physical training. Bitbrain Technologies makes a training system for the brain to accelerate information processing and improve concentration.



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# Cognitive and Neural Optimization continued

Cognitive and neural technologies promise to optimize brain function.

## DISRUPTIVE IMPACT

More data is needed to analyze the results of neuro optimization devices, but there are now dozens of early and mid-stage companies working in this space. Given conclusive evidence that these systems are able to significantly enhance cognitive performance, we can expect to see initial adoption in a range of competitive fields—followed, in all likelihood, by complex attempts to regulate the use of the technology.

## EMERGING PLAYERS

- Halo Neuroscience
- Bitbrain Technologies
- Reflexion



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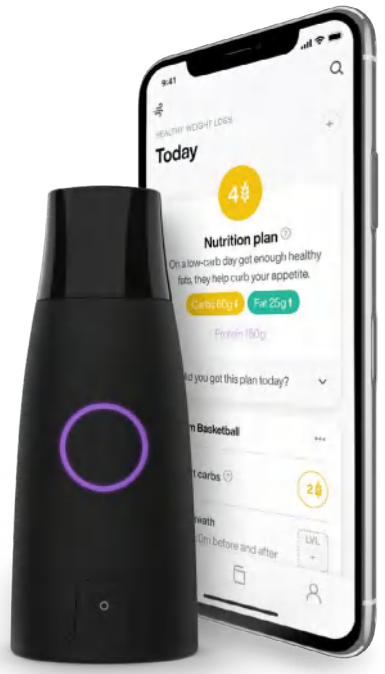
1ST YEAR ON THE LIST

# Metabolic Monitoring




Lumen determines whether fats or carbs are being used for fuel.

## KEY INSIGHT

**Metabolism can be monitored using breath, and new devices use machine learning to determine the body's metabolic rate in real time. The respiratory exchange ratio, or RER, is the ratio of carbon dioxide produced in metabolism and the oxygen used, and indicates which fuel—carbohydrates or fats—is being metabolized to supply the body with energy.**

## EXAMPLES

Two sisters with doctorates in physiology developed a metabolic monitor while training for an Iron Man competition to measure carbon dioxide using a Bluetooth sensor. Lumen is now a more comprehensive automated metabolic monitor that looks like a vape device and connects to a mobile app, which provides recommendations for training and meals.

For serious athletes, the Pnoē Metabolic Analysis System offers measurements of metabolic, heart, lung, and cellular function. After a baseline test, it creates personalized workouts and nutrition plans, and recommends specific types of exercises. Cosmed's K5 is a wearable, portable metabolic system that tracks exercise, heart rate, and stress.

## DISRUPTIVE IMPACT

Metabolic monitoring is useful for athletes in training, hospital patients, and people hoping to optimize how their bodies use the food they eat.

## EMERGING PLAYERS

- Breezing
- Cosmed
- Lumen
- Pnoē



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1ST YEAR ON THE LIST

# Prescription-Strength Gaming

EndeavorRx is an FDA-approved game that treats ADHD.

## KEY INSIGHT

**While we often hear research about the addictive nature of video games, certain types of games can have beneficial therapeutic effects. Gaming has served as a therapeutic tool extending all the way back to the beginnings of virtual reality.**

## EXAMPLES

Early VR systems were intended to help treat post-traumatic stress disorder. Now dynamic gaming experiences are being developed to treat attention deficit hyperactivity disorder (ADHD) in children. In 2020, the Food and Drug Administration approved EndeavorRx, a first-person racing game developed by a neuroscientist at the University of California–San Francisco that significantly improved clinical markers of attention in patients with ADHD. It looks like a kids video game, but the stimuli target and activate the prefrontal cortex. As game play progresses, it adapts and personalizes treatment. Harvard University and Massachusetts Institute of Technology researchers developed The Guardians: Unite the Realms to address behavioral-activation therapy for depression. It serves to break rumination loops and uses the same psychological tactics that mobile apps rely on to goad people into spending more attention or money—but instead uses the tactics to improve moods and emotional states.

## DISRUPTIVE IMPACT

It will take time for the long-term effectiveness of therapeutic gaming to be determined, but with promising initial results, this field is due for growth. Therapeutic games could serve as the backbone of telehealth for sufferers of chronic illness or those under remote patient monitoring. Games played in the home would generate detailed patient data and communicate it directly to the doctor, who would adjust treatment accordingly—all without requiring an office visit, and neutralizing the bias of unreliable self-reported patient data.

## EMERGING PLAYERS

- Azure Kinect
- Intel RealSense Depth Camera
- MIT Media Lab
- EndeavorRx
- Akili
- The Guardians: Unite the Realms



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6TH YEAR ON THE LIST

# Digital Fitness and Training

The EMStyle smart bodysuit and mobile app allow you to track your workouts through your phone.

## KEY INSIGHT

**The last few years saw the rise of smart fitness equipment including mirrors, bikes, and treadmills. The pandemic accelerated sales and helped the market grow significantly.**

## EXAMPLES

In 2020, memberships to Peloton (the connected bike and treadmill platform), surged 232% to $757.9 million. JaxJox KettlebellConnect is a kettlebell set that tracks performance using Bluetooth. Mirror is an interactive gym masquerading as—wait for it—a full-length, wall-mounted mirror. It has recorded or live classes, and the smart mirror surface helps you adjust your form. The Hydrow rower is a connected rowing machine with adjustable resistance levels and prerecorded workouts. FightCamp Gym is a punching bag that connects to classes on iOS devices. YogiFi Series-1 is a connected smart mat that tracks movements, offers haptic feedback, recommends wellness programs, and includes aroma diffusers. This year, Samsung announced Smart Trainer, a device that offers real-time feedback on exercise routines, and Xenoma launched its e-skin EMStyle bodysuit with 24 electrodes to stimulate muscles and provide a full-body workout.

## DISRUPTIVE IMPACT

There are multiple intended settings for smart fitness equipment—amid the pandemic, as individuals and families invested in their own private spaces and adapted to extended spells indoors, smart fitness equipment for the home saw a pronounced spike in demand. But as home equipment becomes more advanced and personalized, gyms and fitness centers will have to upgrade their equipment to compete, especially as home subscription plans undercut in-person membership rates.

## EMERGING PLAYERS

- Peloton
- Ultrahuman
- YogiFi
- CLMBR
- Sworkit
- Oculus Quest 2
- Ergatta Rower
- Hydrow Rower
- Samsung
- FightCamp Gym
- Mirror
- Tonal
- JaxJox



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6TH YEAR ON THE LIST

# Sleep Tech

Somnox's robot simulates the feeling of sleeping next to a parent.

## KEY INSIGHT

**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 Mayo Clinic—but a variety of factors, ranging from anxiety and stress to noisy streets or a partner who snores can interrupt sleep cycles. New technologies promise to optimize sleep, even in challenging circumstances.**

## EXAMPLES

The OOLER sleep system by ChiliSleep automatically prechills the bed to the user's desired temperature using a connected mattress cover and a connected weighted blanket, and then slowly increases the morning temperature for natural waking—instead of a jarring alarm clock. 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, just under the mouth. After a few nights' sleep, the analysis goes directly to the user, avoiding a visit to a sleep center. The Apollo Neuro, an ankle or wrist device, uses gentle vibrations to improve heart rate variability, resilience to stress, and, ultimately, improved sleep.

## DISRUPTIVE IMPACT

Sleep tech is a growing business, with a flurry of connected blankets, wearable monitors, and robots ready to optimize the hours people spend in bed. Sleep tech is big business, too: By 2026, the market size could be upward of $30 billion.

## EMERGING PLAYERS

- Somnox
- ChiliSleep
- Sunrise
- Beddr
- Oura
- Dreem
- Sana
- Ebb Therapeutics
- Sleep.ai



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# Scenarios

## Scent Diagnostics

### Near-future neutral scenario

Augmented reality can change the way we see the world, but it could just as easily change the way we smell it. Health care reaches new levels of diagnostic precision when wearables are integrated with enhanced olfactory sensors. These hypersensitive wearables can "smell" the first traces of a medical emergency or oncoming illness before the patient realizes anything is wrong. This smart "nosewear" can detect the early signs of a stroke, which can affect the victim's sense of smell, or subtle evidence of diseases like Parkinson's and malaria, which are shown to be detectable by the sensitive noses of sniffer dogs. The technology is now a key component of a doctor's toolkit, and a powerful detection tool in preventive care.



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9TH YEAR ON THE LIST

# Wearables and Biointerfaces

**The green light of functional fibers glows.**
Image courtesy of AFFOA.

## KEY INSIGHT

**Consumers can currently choose among more than 1,000 wearable devices, including watches, earbuds, adhesive and pocket-size sensors, headbands, fabrics, and others. We are undergoing a gradual transition from devices that we carry to devices that we wear. As price points become lower and 5G networks are built, wearable devices will enter the global mainstream.**

## EXAMPLES

It's important to remember that the wearables market includes more than smart fitness bands and smartwatches. There are devices for glucose monitoring, smart earphones that can amplify or mute ambient sound, and even full-body haptic suits for athletic training and gaming. Wearables are gaining independent connectivity, meaning that a new generation of devices will no longer need to be tethered to a smartphone or computer to see and report data, adjust settings, and archive information.

## DISRUPTIVE IMPACT

Companies should begin to develop strategies for emerging wearable systems, even if they are outside of the health and wellness space. Key questions to ask include: How will your organization interact with consumers via wearables? How will consumer expectations change as a result of wearables? What is the business case for wearables within your organization?

## EMERGING PLAYERS

- Withings
- Ringly
- Spire Health
- Sony
- Oculus
- Athos
- Amazon
- Harvard University's Wyss Institute for Biologically Inspired Engineering
- DARPA
- University of Washington's Center for Neurotechnology
- Tufts University
- Robotics Institute at Beihang University
- Samsung



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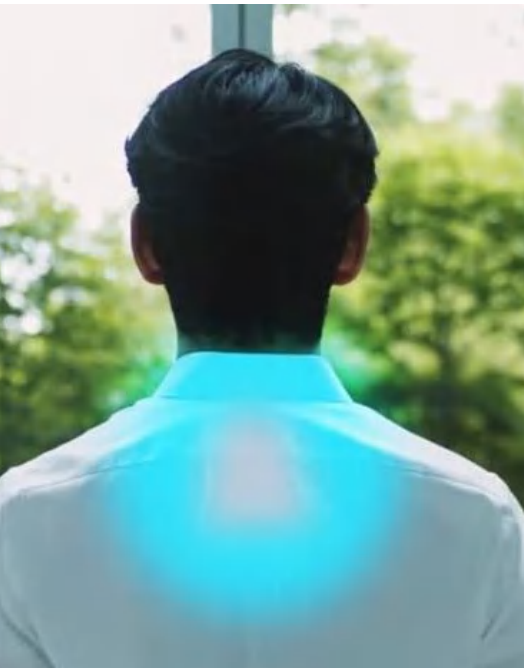
# Wearables and Biointerfaces Trends



Sony's wearable air conditioner.

## Emerging Wearables

### COVID-19 Sensors

The BioButton is an FDA-cleared, medical-grade wearable designed to be worn all the time. The device tells users if they've been in contact with someone who has COVID-19, and it also monitors temperature and other vital statistics. Its personal screening system is housed in single-use disposable patches that adhere to the skin.

### Cloud-based Wireless Body Area Networks

Wireless body area networks (WBANs) communicate information from your wearable devices back to medical servers, app manufacturers, and your home computer. Sensors, such as devices to monitor your heart rate or oxygen level, collect data and send it back to a central hub (most often, your smartphone), which then relays the information to a medical team or health care monitoring service. There are a lot of benefits: Rather than moving into an assisted living facility or spending a lot of time in the hospital, certain patients can live in their own homes while receiving virtual care. Cloud-based systems allow for the continuous transmission of your data and real-time analysis for issues like chronic disease (hypertension, high blood pressure, asthma). This trend is still in very early stages and will be accelerated as 5G networks proliferate, since a more advanced network will lead to less lag and could help secure personal data.

### Adaptive and Assistive Wearables

By serving as replacements for human limbs, exoskeletons and soft exosuits help enhance human mobility for the differently abled or for patients recovering from traumatic injuries. Advanced articulating mechanical systems and neurointerfaces are making big strides in this field. The hard exoskeletons used today will begin to morph into smaller components and more adaptable designs. Researchers at the Robotics Institute at Beihang University are developing new lower-body gear that is lightweight and responds in real-time to the wearer. Meanwhile scientists at Harvard University's Wyss Institute for Biologically Inspired Engineering are researching how to transition from soft exosuits to implanted neural interfaces—think tiny sensors worn beneath the skin—that will someday help to control neuromuscular activity to help people walk.

### Commercial Full-Body Exoskeletons

You've seen them in movies like "Iron Man," "Dave," and "Avatar": powered suits that give average workers superhuman abilities. Harvard's Biodesign Lab is developing next-generation soft wearable exoskeletons that use innovative textiles to provide a more conformal, unobtrusive, and compliant means to interface to the human body. Sarcos Robotics's Guardian XO is a battery-powered suit intended for construction sites, mines, and factories. Built to enhance worker productivity, the suits help people lift heavy loads—up to 198 pounds—without back strain. Ekso Bionics, which develops medical-grade exoskeletons, created a vest intended to help workers more easily perform overhead tasks.

### Wearable Air Conditioners

In Japan and China, workers who must wear protective suits during the intense summer heat for years have worn tiny wearable fans to circulate generated air within their suits, while ventilation flaps allow the warm body heat to escape. But miniature, wearable air conditioners will soon be available to the average consumer. Sony developed the Reon Pocket,



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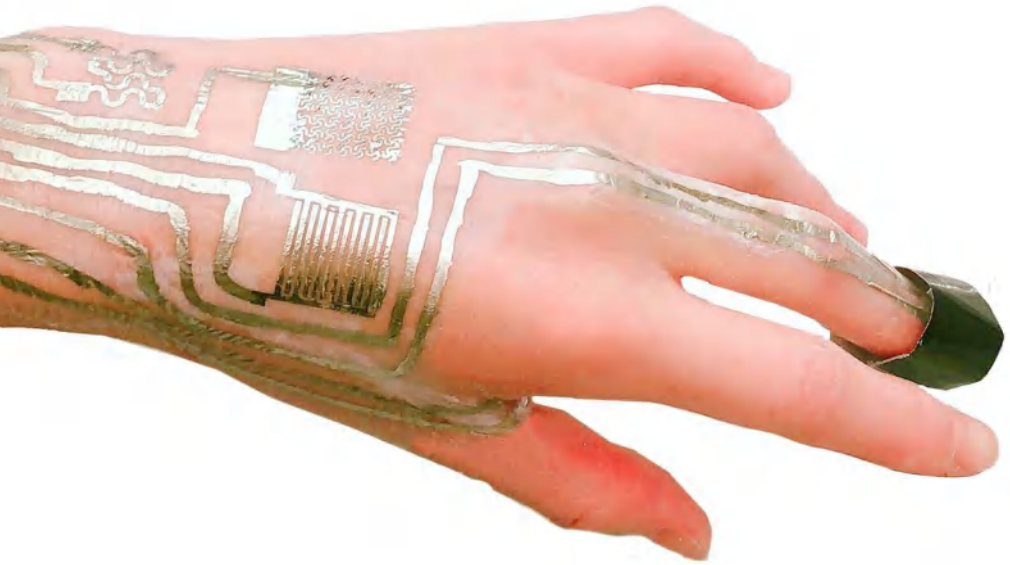
# Wearables and Biointerfaces Trends



**Electrodes and temperature sensors are directly printed and sintered on the skin surface.**
Image courtesy: ACS Applied Materials & Interfaces.

which relies on the Peltier effect to move heat between objects using electrical currents. In place of a servo motor and fan, this device is flat and embedded into an undershirt. Your mobile phone controls the thermostat, cooling your body by 23 degrees Fahrenheit or heating it by 14 degrees Fahrenheit.

## Connected Fabrics

Considering how much behavioral, biometric, and ambient data it could potentially capture, our clothing has untapped potential as a sensory interface. In the past, connected clothing required wires and sensors, making fabrics stiff or uncomfortable. That's starting to change, and it should bring more smart clothes to the masses. The Fibers@MIT research group is working on a fabric computer, with architectures that allow fibers to communicate with each other while retaining the conventional qualities of cloth. Soliyarn is working on imperceptible, flexible sensors woven into self-heating gloves for the U.S. military. The startup is also developing smart pajamas and sleep-sensing masks, while others, including a collaborative effort from Under Armour and football superstar Tom Brady, have developed sleepwear that emits infrared energy for faster muscle recovery following a hard workout. Pivot Yoga makes connected yoga pants—you read that right—that monitor your downward dogs and help you adjust your form. The connected clothing syncs to an app, and a digital assistant offers tips, such as rotating your left hip or moving your feet three inches back on the mat. Spire Health makes a fabric coating for bras and underwear to help track breathing and stress levels.

## Touch-Sensitive Materials

Researchers are developing new prosthetic skins and limbs that restore not just movement but touch as well, through haptic tactile sensations. In 2018, researchers at Johns Hopkins University created an electronic skin to help restore a sense of touch to amputees. Dubbed "e-dermis," it re-creates tactile sensations (including pain) by sensing stimuli and sending the corresponding signal back to the user's peripheral nerves. Interdisciplinary researchers at the Center for Wearable Sensors and the Center for Brain and Cognition at the University of California–San Diego are combining materials science and psychophysics to map exactly how humans perceive touch. This research lays the groundwork for advanced prosthetics, and we've already seen some exciting developments. Neuroscientists at the University of Chicago are experimenting with touch-sensitive robotics and rhesus monkeys, which have the most similar neural-sensory biology to humans—they have successfully simulated the sensation of touch by stimulating certain areas of the brain. A team of scientists from the Lausanne and Sant'Anna School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# Wearables and Biointerfaces Trends

of Advanced Studies and the Agostino Gemelli University Hospital developed a bionic hand that transmits a realistic sense of touch; it's already in use, restoring sensation to a woman who lost her hand in an accident 25 years ago.

## Mature Wearables

### Watches

Smartwatches offer a wide array of functionality. They are digital wallets, diagnostic tools, fitness trackers, phones, and miniature screens on which to view texts and social media posts. Traditional watchmakers and big tech giants now sell hundreds of different smartwatches. Some models, like the newest Apple Watch, no longer require a mobile phone for pairing; it can connect directly to cellular networks and can perform much of the same functionality as a smartphone. A model built by the Future Today Institute in 2016 showing that smartwatch adoption is a contributing factor to the decelerating growth of the smartphone market continues to hold in 2021.

### Rings and Bracelets

Amazon's Halo smart wristband made headlines when it launched last year. The device listens to your voice, tracks and predicts mood, and optimizes caloric intake and fitness. It also connects to Amazon's digital voice assistant, essentially making it a wearable Alexa. PayPal has been researching its own connected ring for fast and easy payments without digging around for a phone or credit card. The Motiv and Oura rings track sleeping habits, while the ORII ring lets you make calls. Google completed its acquisition of Fitbit in early 2021, potentially threatening Apple's domination in the watch market. Rings and bracelets aren't meant as complete replacements for smartwatches, but for developers looking for single-task application opportunities, rings and bracelets offer a good alternative to more programming-intensive watch interfaces.

### Hearables and Earables

In-ear computers, otherwise known as earables, are here. The Noopl smartphone attachment aims to enhance audio clarity in noisy environments. The JBuds Frames allow users to augment audio as they wish, using a snap-on speaker device for glasses. Sony's 360 Reality Audio uses object-based spatial audio technology to enhance sound; setup requires that you allow photos of your ears to be scanned and analyzed and stored on Sony's servers. Apple's AirPods team is working on biometric sensors that will eventually monitor temperature, perspiration, and heart rate during exercise or sports. Starkey's Livio AI uses an array of sensors and AI to modulate external sound—if you're someone who complains that restaurants are too loud, this device promises to help you hear better, and can also act as a digital assistant. New iterations will track many personal metrics, including cognitive activity and your engagement patterns with other people, and be able to translate 27 languages in near real-time.

### Head Mounted Displays

Virtual reality is commonly experienced through wearable headsets, the next generation of which will collect your biometric data and other personal information in order to provide added functionality. These head-mounted displays could track your movements, pupil dilation, heart rate, and other biometrics, and use that data to curate your simulated environment in real time. (See: New Realities.)

### Smart Glasses

The world's largest technology companies—Apple, Amazon, Google, Microsoft, Facebook—are all working, in some way, on connected devices that you wear over your eyes. Facebook and RayBan intend to launch AR glasses in 2021. Amazon's Echo Frames debuted in 2020; for now, they only offer Alexa audio functionality, but AR features are on the horizon. Apple's glasses will work with the Watch and iPhone, but don't yet have a launch date.

### Smart Shoes

Nike's self-lacing Electric Adaptable Reaction Lacing shoes adjust to the contours of your feet. French insole manufacturer Digitsole makes connected insoles that fit inside the shoes of cyclists or runners and provide them with data feedback. They can also keep your feet warm. Under Armour makes connected running shoes with foam soles that include an accelerometer, a gyroscope, a battery, and a Bluetooth module. The shoes collect and store data, freeing you up for a tracked jog without your smartphone. They also set a baseline the first time you use them, and then track your distance, stride length, and running cadence over time.


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# Wearables and Biointerfaces Trends

Amazon's Halo is a fitness band with emotion detection.

### Smart Gloves

In Kenya, a researcher invented smart gloves that can translate sign language into speech. The system, called Sign-IO, uses gesture recognition with sensors embedded in the gloves. Canadian researchers at Simon Fraser University designed a set of interconnected gloves to help transmit a sense of touch through the internet. When someone moves her fingers in one glove, her actions are sent to her partner wearing the other. Sony has been filing patents for haptic glove controllers, which would simulate the physical sensations of slicing, punching, and shooting.

## Biointerfaces

### Nanomesh Tattoos

Imagine wearing a temporary tattoo rather than taking a handful of pills every day. Research is underway on nanomesh technology as a diagnostic and drug delivery tool. Scientists at the Institute for Basic Science and Seoul National University in South Korea, the University of Texas at Austin, the University of Tokyo, Stanford University, and the University of California–San Diego are all working on electronic second skins. MC10 has already created microscopic, organic semiconductors and carbon nanotubes that stretch and flex and can be powered wirelessly. The system, called BioStampRC, is far thicker than a tattooable, but the idea is the same—and it's only a matter of time before the technology shrinks.

### Dissolving Bioelectronics

For many people, implanted electronics are required to live a healthy life, but receiving the implants can require costly surgery, and devices sometimes need maintenance and replacement parts. In 2018, scientists at Northwestern University revealed new research on flexible, dissolvable electronic materials. In one case, they showed how the materials could be used during surgery. If nerves have been severed, doctors suture them back together and reawaken them using electrodes and gentle electrical stimulation—but they typically don't have enough time in the operating room to provide that restorative therapy beyond what would be minimally required. The team at Northwestern demonstrated how dissolved electrodes could be used to wirelessly transmit the electrical signal and stimulate repaired nerves for several days, which could cut recovery time in half. Once the therapy is finished, the materials break down and are excreted. The study was done in rats, but it shouldn't be long before we start to see clinical applications in humans.

### Nanobots

Tiny robots capable of delivering medicine to a specific area of the body, or assisting with microsurgery, have arrived:



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# Wearables and Biointerfaces Trends

CuteCircuit's shirt lets people feel music and receive virtual hugs.

They can be steered and threaded, and they can unfold to patch wounds, dislodge swallowed objects, perform biopsies, and deliver targeted medications. Researchers at the University of California–San Diego showed how a nanobot, propelled by gas bubbles, could successfully deliver medicine inside of a live mouse without causing injury. California Institute of Technology scientists developed an autonomous, molecular robot, made of a single strand of DNA, that treats the inside of the human body like a distribution warehouse. The nanobot can walk around, pick up molecules, and deposit them in designated locations. In 2018, scientists at the Chinese University of Hong Kong unveiled a new way to use nanobots within the body. Millions of tiny, magnetic shape-shifting nanoparticles can extend, merge, and collaborate in a swarm. In practical terms, this means that a surgeon could direct the swarm to assist with eye surgeries, for example, and to deliver targeted medicines. In 2019, researchers at the Massachusetts Institute of Technology Department of Mechanical Engineering figured out how to create arrays of nanoscale magnets that respond to magnetic fields using a technique called electron-beam lithography, resulting in magnetically reconfigurable robots at scales of just a few micrometers. (For comparison, a strand of hair is about 100 to 150 micrometers wide.) In one instance, they made a microscopic bird-like structure that could flap its wings and move as directed. This could someday allow surgeons to perform operations on individual blood vessels or to manipulate single cells. The grand hope with all of these technologies is that nanobots will replace one-size-fits-most medications and therapies, and treat uniquely specific ailments without causing side effects.

## Smart Threads

"Smart thread" uses electrical currents to transmit information to doctors following surgeries. Think of smart thread as a sort of temporary smart system, stitched into the skin, that connects to a smartphone or other medical device and reports on your glucose levels, diagnoses an infection, and alerts hospital staff if your body is chemically out of balance. Researchers at Tufts University have successfully embedded nanoscale sensors and electronics into surgical thread that can be used for suturing. At the University of California–Berkeley's School of Information, researchers are experimenting with smart threads that can change color. These nonsurgical threads are coated with thermochromic paint that changes color when jolted with electricity. Smart thread is just emerging from experimentation, but initial test results show that it can be successfully used as a diagnostic device.

## Skinput Systems

Nearly a decade ago, Microsoft experimented with "skinput," which turned a person's arm and hand into an interactive interface. You could answer a call by tapping your fingers or skip a song on your playlist by pressing your palm. In the brand's Hololens 2 extended reality headset, simple taps against your skin activate features. Google's Project Soli, announced in 2015 during the tech giant's I/O developer conference, is a miniature radar that understands human motions at various scales, from the tap of your finger to the movements of your body. Since then, Google's ATAP (Advanced Technology and Projects) division has been advancing that skinput idea: In 2018, the Federal Communications Commision approved its proposed tests of a new chip that uses radar to track micromotions. We're already transitioning from physical to digital buttons; soon skinput may teach consumers to live without any buttons at all.


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4TH YEAR ON THE LIST

# Brain Machine Interfaces

In 2020, Elon Musk demonstrated a plan to create a working brain-to-machine interface with a working prototype implanted in pigs.

## KEY INSIGHT

**Computer scientist Jacques J. Vidal was the first to talk about "brain machine interfaces" in the early 1970s, and since then the term has grown to encapsulate a range of technologies that serve as interfaces between the brain and the outside world. Researchers are finding new ways to connect humans and other mammals directly to computers—and humans to one another.**

## EXAMPLES

Elon Musk hopes to someday outfit us with small, wearable computers with threads extending directly into our brains. Last year, Musk's Neuralink tracked a pig's brain activity using implanted sensors, and the Food and Drug Administration granted the company a breakthrough device authorization to move quickly on its human research. In 2019, Neuralink built a robot to implant tiny, ultrathin threads deep into the brain—a step closer to complex brain-machine interfaces. The Pentagon has its own body mass index projects that use both threads and pulsating lights. Kernel intends to measure and stimulate the electrical impulses of neurons. Synchron's implantable device the Stentrode aims to give paralyzed patients direct brain control of mobility-assistive devices. Neurable is working to let people use brain activity to control software and devices, and NextMind raised $4.6 million to create noninvasive brain command tech for gamers.

## DISRUPTIVE IMPACT

Much of the research to date has focused on rehabilitation. With these human-machine interfaces, people can communicate via thought alone, which promises new options for those suffering from stroke, paralysis, and aphasia. But research is going even further than that: Facebook has been working on several BMI projects, including a noninvasive headband that would read thoughts before we say them aloud. In a partnership with the University of California–San Francisco, researchers used sheets of electrodes placed on the brains of volunteer test subjects to see how much of their thoughts could be read. The social media juggernaut, which also owns VR company Oculus, is working toward a headset that might someday allow us to control music or VR environments simply by thinking.

## EMERGING PLAYERS

- Neuralink
- Neurable
- BIOS
- NeuroScouting
- NeuroPace
- MindMaze
- NextMind
- Bitbrain Technologies
- Boston Scientific
- Oculus



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# Expert Insight

## The Post-Pandemic Optimistic Future: From COVID to Consumerism

**Stephen K. Klasko, M.D., M.B.A.**

President and CEO,
Thomas Jefferson University and Jefferson Health

Distinguished Fellow,
World Economic Forum

I'm convinced the globe faces two existential threats that demand disruption of our businesses, our policies and indeed our lifestyles: climate change and health assurance for all.

Both will require disruption in our way of thinking, creative partnerships with entities that have not worked together to create new ecosystems, and the use of augmented intelligence and other new technologies that may be game changers if constructed properly.

Many have theorized that the increased use of telehealth during the COVID-19 pandemic will become the "iPhone moment" for healthcare, where finally healthcare joins the consumer revolution by bringing care to the home and we begin to build "healthcare at any address."

But there's a twist: We have to ensure that the shift to mobile, digital healthcare is ethical, equitable, and sustainable.

Just as climate change cannot be solved by the energy industry

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> Just as climate change cannot be solved by the energy industry alone, health assurance cannot be solved by the healthcare delivery industry alone.

alone, health assurance cannot be solved by the healthcare delivery industry alone. The fourth industrial revolution can be defined in a pretty non-threatening way. It's the blurring of boundaries between the digital, physical, and biological worlds. It's a fusion of advances in artificial intelligence, robotics, the internet of things, genetic engineering, quantum computing, 5G, and the kitchen sink of exciting new technologies that will blossom in the next decade.

The impact of a digital economy on healthcare will be immense, and I am hopeful that in a few years we will not just be talking about the technology of self-driving cars, but also about how we can use these technologies to create "self-healing humans."

**Here's my framework for equitable and sustainable models of change:**

1. **Start with ethics.**

   Trust is more important than technology. Ethics must be injected into product development at the very earliest stage, when values are being assessed. Do not wait until a product is ready for market and then ask marketing to make it trustworthy.

2. **Reach across industry.**

   We talk and plan in silos, but health assurance only comes when our industry talks with those involved in food, transportation, education, policy, and the creation of jobs. We need to move social determinants of health to the mainstream of clinical operations and global payment models.

3. **Intellectual property is the new gold, not data.**

   We must understand how IP is derived from the personal data of our patients, and create bright lines for enhanced consent in the use of this data.

4. **Never forget the human in the middle.**

   As online meets offline (OMO), the excitement tends to focus on the technology. But what's equally important is focusing on humans, on new roles for clinicians in the OMO world, on new services for patients. And on what I call health assurance, by constructing a system where the primary goal is a healthy and happy life for all.



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> I am hopeful that in a few years we will not just be talking about the technology of self-driving cars, but also about how we can use these technologies to create 'self-healing humans. '

5. **Perhaps, most importantly, there is no such thing as "non-disruptive" disruption.**

   Disruption, by definition, will be painful to those who don't want to think differently as new ecosystems are built.

If we are to globally move from sick care to health assurance and bring health into homes and neighborhoods, the home should be the locus of care delivery. It's time to strip from hospitals everything that can be done in an outpatient setting, leaving hospitals as the location for the very sick and for very complicated therapy. This healthcare "revolution" will require passionate leaders advocating for change—in essence, an army of Greta Thunbergs! Let's hope the once-in-a-century COVID-19 pandemic of 2020 heralds a new century of global health assurance starting in 2021.

**

*Dr. Stephen Klasko is an advocate for transformation in healthcare and higher education. As President and CEO of Philadelphia-based Thomas Jefferson University and Jefferson Health since 2013, he has led one of the U.S.'s fastest growing academic health institutions based on his vision of the future of higher education. In 2020, he was named the first Distinguished Fellow of the World Economic Forum. This year he published Un-Healthcare: A Manifesto for Health Assurance, with Hemant Taneja, as well as the textbook, Patient No Longer: Why Healthcare Must Deliver the Care Experience that Consumers Want and Expect.*



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# Application

## STRATEGY

For chief strategy officers working in health care systems, hospitals, insurance, and the pharmaceutical industry, decisions must be made about the longer-term direction of organizations given the staggering pace of innovation coming from external disruptors. The COVID-19 pandemic accelerated private equity and venture capital investment in a number of different areas, from biometric monitoring to remote patient care. CSOs should pay special attention to the big tech companies as potential sources of opportunity and risk. Now is the time to develop a long-term strategy for your organization's evolution.

## INNOVATION

For those working in the health tech space, this is an incredible time. As wearable devices reach the mainstream, 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 patient record sharing. Innovation teams can develop their visions for the future, using signals and trends to develop plausible scenarios. From this work might come new products, changes in strategic direction, or future business models.

## R & D

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." In 2021, 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. R&D teams can mitigate the need for speed right now by working together with product and marketing teams on their expectations and road maps.

## RISK

Data collected from health tech and wearables is valuable, and the industry is a target. In 2020, there were numerous cyberattacks on hospital systems. Mercifully, the devices people rely on—pacemakers, insulin pumps—haven't been hit with attacks. Chief risk management officers and those who work in risk-related positions can play a critical role in making sure that not only are devices safe, but the ancillary systems that collect and distribute data are encrypted and secure.



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# 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 about the futures of health care, medicine, and wearables:

1

Is our company tracking disruptions outside of our immediate industry?

What does the Amazon Pharmacy case study tell us about our business?

2

What parts of our business make us a target for disruption?

How could new business models introduced by new entrants pose a threat?

3

Are our digital transformation efforts keeping pace with the changes in health, medical, and wearable technologies?

What assumptions must hold true for our current strategy to succeed?

How will we make needed changes?



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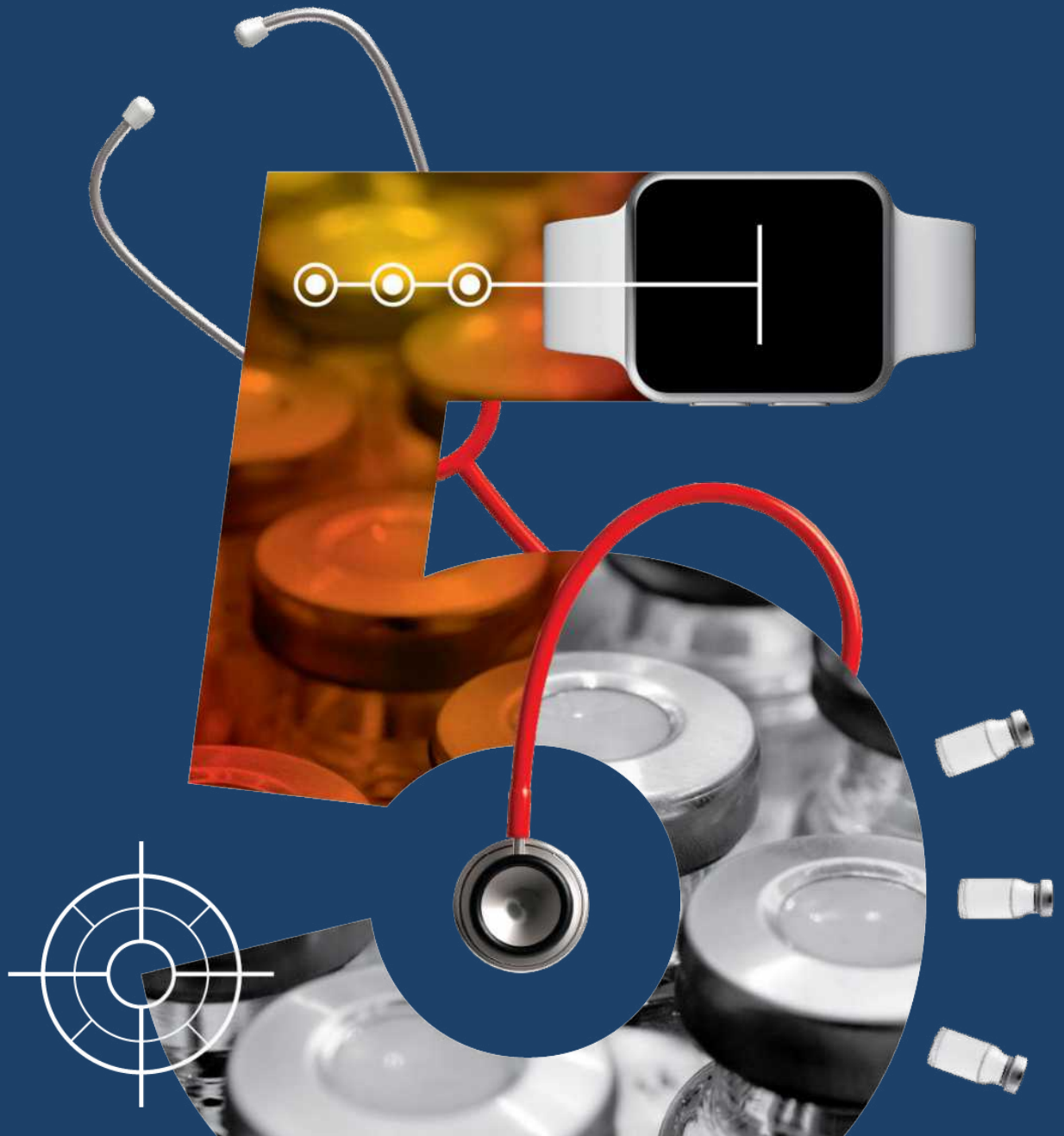

Future Today Institute

Volume 6 of 12

14th Annual Edition

# 2021 Tech Trends Report

Strategic trends that will influence business, government, education, media and society in the coming year.

## Home Automation

## Consumer Electronics

Future Today Institute

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# Home Automation & Consumer Electronics Summary

- The Home of Things (HoT) industry is growing, with demand driven by working, exercising, and learning from home.
- Homes are becoming sentient: Automated systems sense and adjust temperature, sound, light, and other functions in real time to support families.
- But the HoT is notorious for security vulnerabilities. Hackers increasingly target HoT devices with botnets and malware attacks.
- Neighborhood mesh networks connect clusters of smart homes to one another. Within the mesh, homes share Wi-Fi, and residents can stay connected to their devices when outside. If a resident loses her keys while running, she can ping the network to find their exact location on the street.
- Artificial intelligence helps monitor and mitigate the HoT's digital emissions and reduce the smart home's carbon footprint.
- Google, Amazon, and Apple are the primary HoT platforms, but their ecosystems aren't always interoperable.
- Rollables are the new foldables: Screens that unfurl and retract will change the form factor of many consumer electronics.


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6TH YEAR ON THE LIST

# GAA Homes

Amazon's ecosystem encompasses thousands of devices.

## KEY INSIGHT

**Despite the proliferation of smart home devices, only a few platforms can connect them all together.**

## EXAMPLES

As prices have dropped for connected home appliances and peripherals, consumer sales have soared for smart devices. Devices that work with platforms created by Google, Amazon, and Apple (we'll call them the GAA) are ubiquitous and increasingly affordable—because a smart home offers rich streams of data that can be monetized. In China, Alibaba, Xiaomi, and Baidu are the predominant providers. The GAA aim to create a seamless experience among the devices in their ecosystems. Amazon's smart electrical plugs; lightbulbs; Fire TV Cube; Ring doorbell, smart door locks, thermostats, and security cameras; and Alexa speakers can together control many of a home's everyday functions. Similarly, Google Home connects to thousands of devices. Telecom firms hoping to create high-margin businesses, rather than act as dumb connectivity pipes, increasingly seek partnerships with the GAA.

## DISRUPTIVE IMPACT

Devices across ecosystems aren't always interoperable. A Google speaker won't interact with devices running on Amazon's smart home platform, for example. While savvy users can buy smart cameras that run on open source tools, the average family needs to choose one of the GAA. The three companies joined the Zigbee Alliance to create and enforce standards for wireless networking protocols used by low-power radios in smart home gadgets and appliances. Still, that doesn't mean Google products will connect with Amazon's, which effectively means we're Google, Apple, or Amazon families.

## EMERGING PLAYERS

- Samsung's SmartThings
- Google Developers
- Apple Developers
- Zigbee Alliance
- Dotdot



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6TH YEAR ON THE LIST

# Home Service Bots

Samsung is making a robot that will pour you a glass of wine.

## KEY INSIGHT

**Service robots automatically perform repetitive tasks around the home.**

## EXAMPLES

The 1980s-era home service robot the Omnibot 2000, by Japanese toy manufacturer Tomy, wasn't a commercial success, but it was useful: It could play back prerecorded sequences on cassette tape, it could roll into your room and wake you at a designated time, and it carried light objects with articulated claw hands or a tray. Fast-forward to 2021, and home service bots are finding a new audience. Samsung's JetBot 90AI+ is a robot vacuum with lidar, a 3D sensor, a built-in camera, and computer vision that allows it to avoid objects and double as a roaming security system. Larger wheels let it maneuver over door thresholds and thicker rugs, and it has an automatic disposal system. The Gladwell Gecko Robot is an automated glass and window cleaner. iRobot's Looj device cleans your gutters, and The Landroid L 20V from tools innovation company Worx is like a Roomba for the yard: It automatically mows the lawn in a desired pattern.

## DISRUPTIVE IMPACT

Samsung calls its Bot Handy an "extension of you" anywhere you need a hand in the home. Still in development, this slender, autonomous bot picks up laundry, brings you drinks, and loads the dishwasher. Bot Care aims to be a personal assistant. While humanoid robots, such as the XR-1 from CloudMinds, are built as all-purpose automated butlers, most service bots are smaller, lightweight and intended to perform single functions. As their functionality improves, service bots will reshape house cleaning, which could have downstream effects on companies that make analog cleaning supplies (paper products, sponges, and sprays). The next wave of bots will include automated clothing cleaners and laundry folders, and service bots that use computer vision to make beds.

## EMERGING PLAYERS

- Savioke
- Neato Robotics
- Trifo



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## GAA Homes and America's Digital Caste System

**Mid-future catastrophic scenario**

In the year 2035, Apple households tend to be wealthier and older. They can afford Apple's sleek, beautiful hardware products available in one of three colors: palladium silvery-white, osmium gray, or dark onyx. Apple's smart glasses, smart toilets, and custom refrigerators carry on its long tradition of pricey products anyone can use right out of the box. Its system comes with spoken interfaces and a choice of two soothing voices, Joost (who has a "unisex higher tone") or Deva (who has a "unisex lower tone"). But convenience comes with a cost. Apple's artificial intelligence (AI) cannot be overwritten. In an Apple home running the air conditioner, you can't open the door for more than a minute or the system will start beeping incessantly. If there's sufficient daylight detected by the sensors in your light bulbs, the Apple system keeps the light switch on lockdown.

We saw a preview of Google's connected home decades ago at the 2018 South By Southwest Festival in Austin, Texas. Back then, the tagline was "Make Google do it," and attractive spokesmodels took small groups around the three-story home to interact with AI-powered appliance screens and connected frozen daiquiri makers. Google's system is less intuitive, but it makes better use of our data—and it offers different levels of service and access. For those who can afford the upgrade fees and have enough tech savvy, Google Green gives families the ability to manually unlock their systems, and they can connect a greater variety of things—such as coffee makers and outdoor irrigation systems—to their homes. Green families can also opt out of being served advertisements, though their data is still collected and sent to third parties. Google Blue is an affordable option with limited unlocking privileges and some additional permissions—and plenty of ads. Google Yellow is the lowest tier. It's free but comes with no override abilities, a small selection of available devices and appliances, and offers limited data protections.

Amazon went in an interesting, but ultimately smarter, direction. A few announcements Amazon made in the fall of 2018 went largely unnoticed, like the launch of its AmazonBasics microwave, which includes a voice interface. Users could put a bag of popcorn in the microwave and ask Alexa to pop it. Tech journalists wrote the microwave off as a novel, silly use for Alexa, and missed the bigger picture: The system was actually designed to get us hooked on subscription popcorn. That's because the microwave tracks both what we're heating up and what we're ordering on the Amazon platform. A new box arrives before you ever have the chance to run out.

Because Amazon was the smartest in its approach with federal, state, and local governments—offering them deep discounts at Amazon.com, patiently working through procurement requirements, and building and maintaining cloud services specifically for them—it became the preferred platform for certain social services in the United States. That is how Amazon discovered how to leverage the long tail of government funding.

Low-income families now live in Amazon Housing, which has replaced city-funded public housing programs in the United States. By every measure, they are far superior to any public housing ever provided through our previous government programs. Amazon Homes are outfitted with connected devices in every room. The former Supplemental Nutrition Assistance Program (previously known as the Food Stamp Program) is currently hosted by Amazon, which provides steeply discounted Amazon-branded household products, food and drink, toiletries, and books. Unsurprisingly, this program works seamlessly. There are never delays in funds being distributed, it's easy to look up the status of an account, and all transactions can be completed without ever having to wait in a long line at a government office. Those living in Amazon Homes must buy most of their things through Amazon while their data is scraped, productized, and monetized for various initiatives. Amazon's AIs are the most pervasive, following Amazon families everywhere they go to collect valuable behavioral data.

The lack of interoperability between AI frameworks and systems led to segregation by our data and household, and that is why we now


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## GAA Homes and America's Digital Caste System

**Mid-future catastrophic scenario**

have a digital caste system. By choosing Google, Apple, or Amazon, you are forced to align your family values with the values of the corporation. Apple families are rich, maybe a little less AI-savvy, and live in fancy houses. Google families might be rich and techy, or middle class and fine with marketing, or complacent with not having a lot of choices in life. There is no way to sugarcoat Amazon families: They're poor, even if they have free access to cool gadgets.

Families are locked into their de-facto home operating systems, and that designation travels with them. It's easier for a Google Yellow family to port into the Blue or even Green level than it is for an Amazon family to port into the Apple system. That's why most families opted in to Google when they had the opportunity. Your status is visible to all of the AIs you interact with. Self-driving taxi services like Lyft, Uber, and CitiCar don't pick up Amazon riders with as much frequency, and cars sent to them tend not to be as nice. Waymo cars exclusively pick up Googlers. For Greens, the car is preset to the rider's desired temperature and ambient lighting scheme, and it drives along the rider's preferred routes. Yellows are subjected to advertising their entire trip.

Advertising isn't the only headache for Yellow Googlers. One downside to all the subsidized (or free) gadgets, appliances, and gear offered to Google Blue, Google Yellow, and Amazon families is that it's impossible to disconnect the AI health and wellness minders, which continually monitor, diagnose, and nudge. A failure to comply with health and wellness minders results in a litany of consequences.

Remember those Amazon Lockers you used many years ago to pick up all the things you ordered on the Amazon app and Amazon.com? They made their way into Amazon Housing. Leaders in the U.S. Health and Human Services Department thought nudging poor people was a clever way to improve health and wellness, so the department issued new policies requiring all public housing customers to be outfitted with Locker technology. The Lockers may look like ordinary pantries, refrigerator doors, and closets, but they act like AI-powered juries. If an Amazon Housing customer hasn't had her exercise that day, the Locker system will decide to keep the freezer closed and won't let her eat ice cream.

It's not impossible to intermarry—occasionally an Amazon will marry into an Apple family—but that old adage "opposites attract" no longer applies. All of our AI-powered dating services now match us based on our data. On the one hand, we no longer suffer under the tyranny of choice since dating AIs have drastically reduced the selection of possible suitors. Yet some choices that once made us uniquely human—like May-December romances or dating someone our parents don't approve of—are less available to us now. In America, society is beginning to feel uncomfortably Huxleian, as we acquiesce, get married, and have babies with our fellow Apples, or Google Blues, or Amazons.


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1ST YEAR ON THE LIST

# Disinfecting Bots

Virus-zapping CLOi robot is the first of a number of autonomous droids LG plans to market in the United States in 2021.

## KEY INSIGHT

**The pandemic resulted in an explosion of COVID-19 tech: devices and gadgets intended to help people mitigate the harms of the virus. Robots capable of sterilization 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 will use 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. Xenex Disinfection Services makes robots that attack deadly pathogens with pulsing, high-energy, broad-spectrum UV light.

## DISRUPTIVE IMPACT

While some hospitals and office buildings experimented with disinfecting robots pre-Covid, they 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. Sales of disinfecting robots may hit $2.3 billion by 2025, up from $341 million in 2019, according to market advisory firm Mordor Intelligence.

## EMERGING PLAYERS

- LG Electronics
- Xenex
- Prescientx
- UBTech Robotics
- MIT Computer Science & Artificial Intelligence Lab



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2ND YEAR ON THE LIST

# Digital Emissions

Data centers are responsible for CO2 emissions.

## KEY INSIGHT

**Collectively, our homes are starting to produce digital emissions. Everything we do online—sending an email, hosting a Zoom call—requires energy, and each of those digital actions leads to carbon dioxide emissions.**

## EXAMPLES

The internet's data is invisible, but it requires physical data centers around the world that must be powered on, cooled, and protected 24 hours a day, seven days a week. 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, companies will continue to work to cut digital emissions. In 2009, Google opened a data center in chilly Hamina, Finland, to cut energy use. The act of cooling IT equipment eats up about 40% of the energy required by data centers. Now, Google will invest in additional cold-climate data centers. Google also uses high-tech evaporative cooling, smart temperature controls, and machine learning systems to automatically adjust energy consumption. Mozilla Firefox's Enhanced Tracking Protection blocks third-party trackers while cutting energy usage when you're online. It also employs search recycling: If you type in the search bar to navigate to a site, it requires data processing and energy consumption. Using autocomplete, rather than manually typing, to navigate back to your intended destination means zero carbon searching.

## EMERGING PLAYERS

- Nokia
- Ericsson
- Firefox's address bar
- DigiPlex
- ICTFootprint.eu

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.



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5TH YEAR ON THE LIST

# Retrofitting Old Homes With New Technology

Smart home technologies, like automatic thermostats, can offer older homes new upgrades.

## KEY INSIGHT

**As smart home devices become more ubiquitous and affordable, people are working to retrofit old homes with new technologies.**

## EXAMPLES

You 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. In the U.S., buying and retrofitting an older home can be more affordable than building a new one.

## 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



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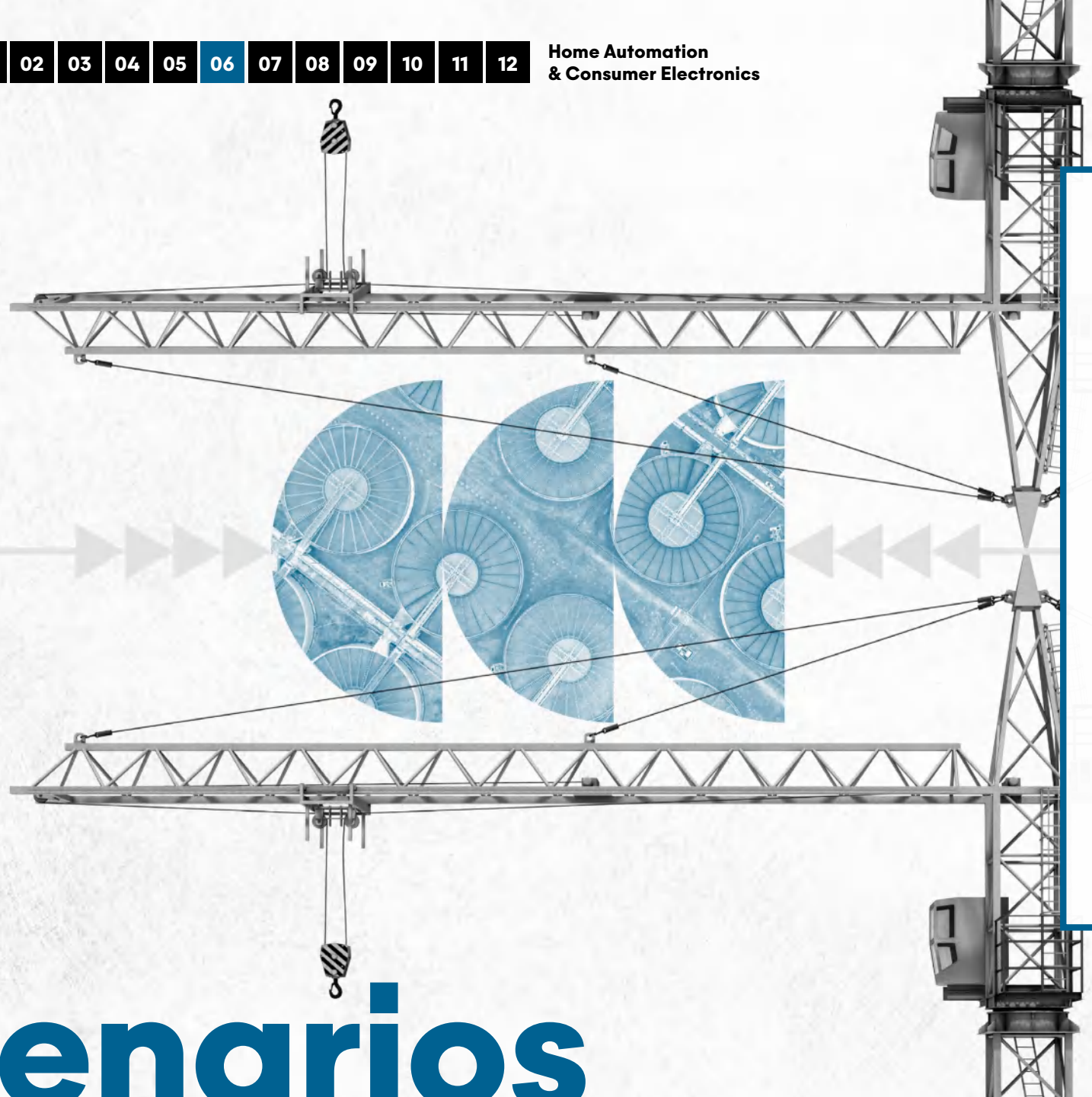

## Regenerative Infrastructure

### Mid-future optimistic scenario

Our city infrastructure has been updated and reconstructed with self-repairing materials, transforming the environments we inhabit. These materials are developed by training algorithms to iterate millions of combinations of periodic elements, targeting specific qualities such as conductivity, elasticity, and stability, and enhancing the resulting materials with electrical charges, sensors, and enzymes created with synthetic biology. This tech has created concrete that seals its own cracks, glass that reassembles when shattered, and metals that detect and counteract corrosion. Self-repairing materials have changed how architects design buildings and how governments engage in city planning, especially since any structures built with the materials are likely to endure for far longer than traditional infrastructure. That said, new construction projects ranging from homes to highways must be planned with extra caution and care, as the results—including the harms or benefits they cause to society—could plausibly survive for centuries.

# Scenarios



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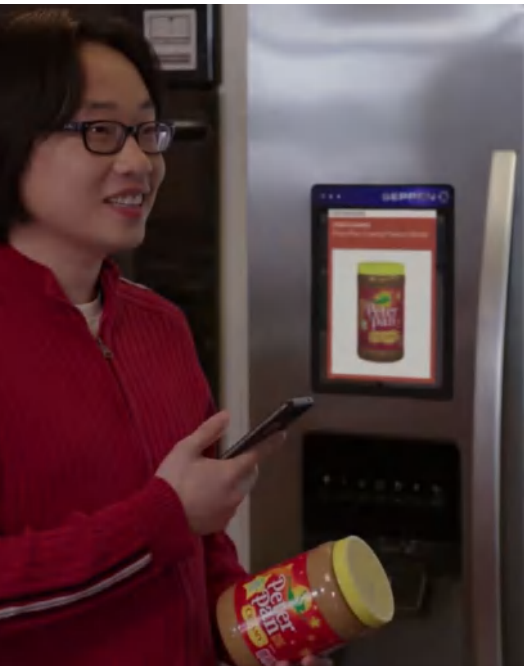
5TH YEAR ON THE LIST

# Forced Obsolescence



On the HBO series "Silicon Valley," Jian-Yang retrofitted the refrigerator with a password and computer vision. (We're pretty sure it broke the warranty.)

## KEY INSIGHT

**Appliance manufacturers build products with intentionally limited lifespans, forcing consumers to throw away old products and continually buy new ones.**

## EXAMPLES

The idea of forced obsolescence is nearly a century old. It was first written about by Justus George Frederick, an early marketer who argued in favor of inducing "people to buy an ever-increasing variety of things, not in order to use them but to activate commerce and discard them after a short period of time." A decade ago, companies that made printers tweaked their technology to prevent the use of generic ink cartridges. Makers of connected home appliances and devices are following suit. A few years ago, General Electric required its refrigerator water filters to use only replacements that include RFID chips. If you don't buy one from GE, which is substantially more expensive than filters made by other companies, you don't get water. Game consoles, mobile phones, e-readers, microwaves, refrigerators, washing machines, and even hospital ventilators are designed to limit repairs.

## DISRUPTIVE IMPACT

Consumer activists in the European Union and the United States have mounted legal action. Dubbed the "right to repair," proposed laws would force manufacturers to allow repairs, interchangeable parts, and common standards.

As more smart home appliances become available, we anticipate arbitrary technical barriers to making those devices work over long periods of time. What's more, by forcibly bricking our devices every few years, companies are creating mountains of waste that will cause future environmental damage. This 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.

## EMERGING PLAYERS

- U.S. Federal Trade Commission
- The Repair Association
- Coalition for Safe and Secure Data
- U.S. Public Interest Research Group
- UFC-Que Choisir



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6TH YEAR ON THE LIST

# Smart Kitchens

GeniCam scans items as you throw them away and automatically reorders them from Amazon.

## KEY INSIGHT

**For the past decade, researchers have been working on 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.**

## EXAMPLES

The Innit platform, launched in 2013, helps kitchen appliances talk to one another, even those from several different brands. In 2019, Innit partnered with Google Home Hub (now known as Google Nest Hub) and other smart home display device makers to help further connect the kitchen. Additional solutions exist: Drop, a smart recipe startup, partnered with LG Electronics to help automate parts of the cooking process. 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

We are particularly interested in Amazon's approach to the kitchen because of the company's foray into groceries, fitness trackers (like the Halo), and health care. Amazon Basics now makes an Alexa-powered microwave, which responds to voice commands. There's also an Alexa-powered coffee maker, Instant Pot, and meat thermometer. Of particular interest: The GeniCan, a little device that attaches to a garbage can and scans everything thrown away and then reorders it for automatic delivery from Amazon. How will Amazon integrate personal data from the kitchen into the rest of its ecosystem? If your Halo knows you've eaten too many calories, will your Amazon microwave allow you to pop your popcorn?

## EMERGING PLAYERS

- Samsung's Digital Appliance Design Team & Lifestyle Labs
- Google's Design Lab
- LG's Mobile Communications Design Lab
- Bosch
- Innit
- Amazon Web Services



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7TH YEAR ON THE LIST

# Smart Home Gyms

FightCamp turns living rooms into boxing rings.

## 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. Smart home gym equipment, such as the 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 payment packages equivalent to the price of a standard gym membership. As our lives become less structured, demand grows for flexible options. FightCamp analyzed its member retention data and found that 85% more people stick to their workouts when using connected at-home fitness equipment.

## EMERGING PLAYERS

- Peloton
- Mirror
- SoulCycle
- Tonal
- Hydrow
- FightCamp



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1ST YEAR ON THE LIST

# Pricing the Curb

A UPS truck driver makes deliveries in New York City using a static parking spot.

## KEY INSIGHT

**U.S. cities are embracing "curb management" tech as e-commerce, food delivery, and rideshare services crowd building-front spaces. Digital tools allow cities to make companies reserve street curb space, to charge dynamically for that space, and to automate parking enforcement. This maximizes municipal revenue opportunities while incentivizing delivery drivers to expedite their drop-offs and pick-ups and thereby reduce traffic congestion.**

## EXAMPLES

The pandemic spurred e-commerce sales, which jumped 71% in the second quarter of 2020 and 55% in the third, according to Salesforce. The result: more freight vehicles, which complicate traffic and safety on city streets. In Aspen, Colorado, trucks from 28 major shippers, including FedEx and Sysco, use Coord's digital curb app to reserve and prepay for delivery zones. Cities set pricing premiums for peak periods, incentivizing drivers to spread deliveries throughout the day. At least 15 U.S. cities are reforming their curb space to better manage competition for deliveries, improve safety, and generate greater revenue. The CurbFlow app identifies idlers in high-traffic areas like airports and cultural venues, detects illegal parking, and counts passengers inside vehicles to enforce carpool lanes and incentivize rideshares.

## DISRUPTIVE IMPACT

The costs incurred by companies from municipal curb management will likely be passed on to consumers, and the free shipping we've enjoyed may disappear. Smart curb pricing will spur a new wave of revenue-generating urban infrastructure that offers more dynamic and detailed pricing structure using new technologies such as cameras, sensors, and apps. This approach could lead cities to charge fees to drivers who take certain streets during high-traffic periods, ultimately incentivizing them to take alternate routes or travel at different times of day. Cities could also charge for excessive trash pickup, especially during snowstorms, or charge for noise pollution, including loud construction and modified drag-racing cars.

## EMERGING PLAYERS

- Coord
- CurbFlow
- City Tech Collaborative (includes Bosch and HERE Technologies)



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3RD YEAR ON THE LIST

# Securing the HoT (Home of Things)

Devices in our smart homes are targets for hackers.

## KEY INSIGHT

**The Home of Things includes routers, security cameras, thermostats, smart TVs, media devices (such as Bluetooth speakers), and myriad other smart devices. Many have security weaknesses, because the technology sometimes relies on outdated software, vulnerable operating systems, or weak authentication mechanisms.**

## EXAMPLES

Everyday people are buying and installing millions of HoT devices without really understanding how they work. Firmware upgrades and software patches are left to consumers, who may not have the technical knowledge to monitor their systems. Outdated applications that were once secure could be riddled with security holes today. After the Mirai botnet took down the East Coast internet backbone using a distributed denial-of-service attack, researchers discovered that connected devices—rather than PCs—had been hijacked and redirected.

## DISRUPTIVE IMPACT

In the near future, burglars will break into homes using computers, not crowbars. Because most people don't consider their connected devices to be computers, they don't monitor them for malware or security flaws. When an unprotected Internet of Things device is connected to a network, it can become infected in minutes. The National Science Foundation launched a project last year to boost IoT security. Led by Dartmouth College, the Security and Privacy in the Lifecycle of IoT for Consumer Environments (SPLICE) initiative will conduct several studies to better understand interface design, embedded systems, wireless networks, radio engineering, and privacy, and it will develop a toolkit to help people secure their homes.

## EMERGING PLAYERS

- Black Hat USA
- SPLICE
- National Institute of Standards and Technology
- European Union Agency for Cybersecurity



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## When Smart Homes Go Dumb

### Mid-future neutral scenario

Smart spaces aren't always so smart. Because nearly every place we frequent, including our homes and offices, are digital environments, technological failures have become an increasingly frequent, and occasionally devastating, problem. With a range of devices and systems at work that don't always properly communicate with one another, breakdowns are not uncommon: Control panels suffer outages, digital locks freeze up, and appliances go dark when you need them most. To limit the fallout from these breakdowns, new smart buildings are retrofitted with low- or no-tech fail-safes. The latest wave of smart spaces are constructed with an analog mode that kicks in when smart features fail so that users can interact with their environments manually, unencumbered by malfunctioning tech. Engineers and designers conceal physical switches and buttons beneath seamless digital interfaces, and include manually charged power sources for critical system components. That way even if we're lulled into complacency by the convenience of smart tech in the built environment, we're not left powerless next time we're forced to snap back to reality.

# Scenarios


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1ST YEAR ON THE LIST

# Neighborhood Mesh Networks

Amazon's Sidewalk program is creating mini-mesh networks in neighborhoods.

## KEY INSIGHT

**A mesh network is a group of devices in close proximity to one another that allows for fast and efficient data routing. Amazon's Sidewalk program is a location-tracking mesh network operating at the scale of a neighborhood.**

## EXAMPLES

Amazon Sidewalk plans to link smart home devices, such as its Ring and Echo, as well as other Amazon products using Bluetooth low-energy, 900Mhz spectrum and other available frequencies. For every device with Sidewalk turned on, internet bandwidth is pooled for a half-mile. The more neighbors who contribute, the more bandwidth available. The mesh network can transmit software and security updates, too. And if consumers are outside their homes but within the mesh, their devices should be able to connect. One early use case: If a consumer loses her keys and has a Tile attached, she can use the Sidewalk network to automatically locate her keys.

## DISRUPTIVE IMPACT

The convenience factor is certainly compelling. If, for some reason, a consumer's Wi-Fi goes down, he can temporarily continue to stay online. Amazon has said that bandwidth usage by each mini-mesh network is capped at 80 Kbps (a fraction of what it would take to stream a video on Prime). Consumers can opt out of the service, but they must know how, because Sidewalk is turned on by default. Sidewalk needs internet service providers to function, but it also siphons some of the consumer relationship from those providers. If Sidewalk is a success, it could influence the future of the cable and telecom industry, including forcing positive changes in the industry's notoriously problematic customer service.

## EMERGING PLAYERS

- Amazon Sidewalk
- Sidewalk Developer Console



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1ST YEAR ON THE LIST

# Rollable Screens

The Oppo X 2021 smartphone includes a rollable screen.

## KEY INSIGHT

**Rollable screens are flexible and adaptable, and they unroll to become larger. Imagine a retractable scroll that can unfurl and snap back into place. Rollable screens are being developed for next-generation mobile phones and portable entertainment (screens for reading, watching videos, and everyday computing).**

## EXAMPLES

Chinese electronics manufacturer TCL has developed a phone and a tablet with a rollable screen. A flexible OLED display is tucked away inside the device; a motor expands the chassis to reveal a larger screen. Users pull the phone to expand it, effectively doubling the screen real estate. The Oppo X 2021 is a smartphone with a continuously variable OLED display that automatically adjusts the aspect ratio of what's being viewed. LG is developing a suite of rollables, including televisions and a phone. Its rollable OLED TV is already in the market, though the $87,000 price tag will keep it out of the mainstream. The company has said that more rollable devices will go on sale in 2021.

## DISRUPTIVE IMPACT

The initial slate of rollables are prototypes and concepts, but the technology has attracted so much attention that companies are rushing to patent their inventions. Oppo applied for 122 patents already, and a dozen cover the scroll mechanism alone. Rollables will continue to evolve, with components shrinking over time. In the future, this could mean rollable smartphones the size of pencils.

## EMERGING PLAYERS

- Oppo
- TCL
- LG



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# Application

## STRATEGY

For chief strategy officers working in consumer electronics, it's time to rethink interoperability and forced obsolescence. Newly elected U.S. officials will pursue antitrust suits against the big tech companies, and the Biden administration is arming the U.S. Federal Trade Commission and the U.S. Consumer Financial Protection Bureau with aggressive teams. This could have a downstream effect on consumer electronics manufacturers. CSOs should model plausible outcomes for the next three to five years and develop alternative business models and pricing strategies.

## INNOVATION

Right now, Home of Things (HoT) devices 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, a coffee machine connects to your alarm clock and brews a cup of coffee that's the right size and strength just as you're waking up—and then an hour later, it brews a different version when your roommate wakes up. Better yet: A coffee machine that also connects to fitness wearables can titrate just the right amount of caffeine per serving. Automated personalization options for shared appliances will unlock new products and consumer demand spaces.

## R & D

This is an exciting time to develop the next generation of smart home technologies. A multitude of breakthroughs in flexible displays, ultrasonic detection, micro-mesh networks, 5G deployment, and metadata scraping—combined with consumer demand for IoT devices—presents a strong argument for continued R&D in home automation. One immediate need: What happens to the HoT if the power goes out and consumers don't own battery backups or generators?

## RISK

The HoT presents numerous risks for ICT companies, internet service providers, platforms, and device manufacturers. Consumers are simply not aware of vulnerabilities. This is an opportunity for hackers as well as for chief information security officers: Securing the HoT should be a top priority for companies in the ecosystem. The U.S. government is creating security standards for IoT devices through the National Institute of Standards and Technology, but companies will need to move faster than the speed of government to protect consumers.



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# 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 about the futures of smart homes and consumer electronics:

1

Is our company tracking disruptions outside of our immediate industry?

What does the emergence of rollable screens tell us about our business?

2

In a world in which smart homes are ubiquitous and neighborhoods have their own mesh networks, what assumptions must hold true for our current strategy to succeed?

How will we make needed changes?

3

What new opportunities does the Home of Things create for our company?

And what new competitors and vulnerabilities will emerge?

How could new business models introduced by new entrants pose a threat?



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14th Annual Edition

# 2021 Tech Trends Report

Strategic trends that will influence business, government, education, media and society in the coming year.

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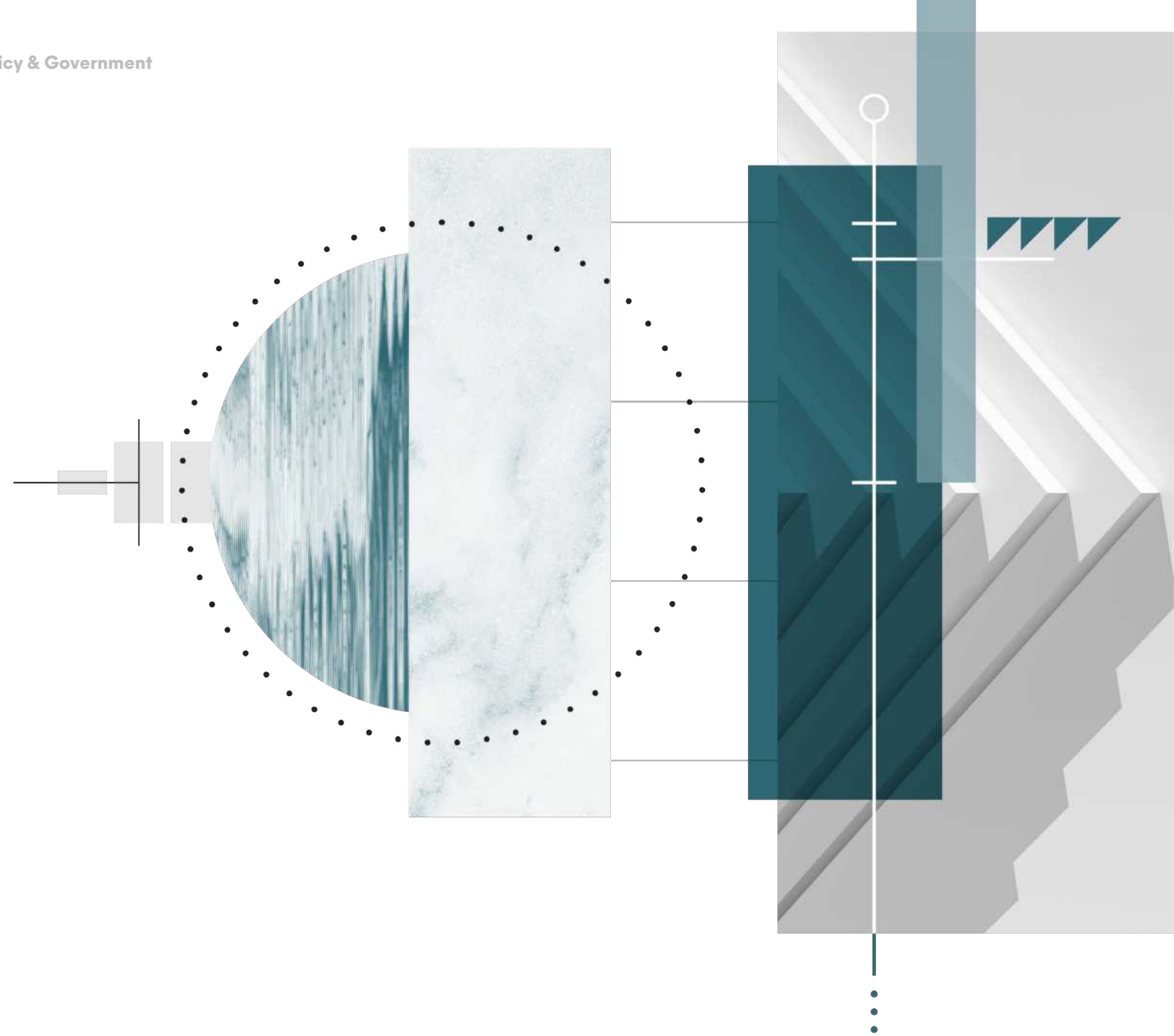

# Policy & Government Summary

- COVID-19 accelerated digital transformation, the adoption of online government services, and universal basic income programs in countries around the world.
- The cloud is controlled by a handful of companies that have the sole ability to determine pricing, access, and standards. "Cloud neutrality" will be debated this year.
- The Biden administration will take more aggressive measures to limit the reach and powers of the world's largest technology companies.
- Countries are pushing for a digital vaccine passport to restart travel, but safeguarding citizens' health data remains a challenge.
- In the U.S., states are starting to exert their own regulatory power. They're suing big tech companies, proposing digital dividend programs, and restricting the use of facial recognition systems.
- High-profile people and companies were deplatformed last year. Lawmakers will debate whether private companies should have the right to take public speech offline.
- Companies will exert new power through corporate denial-of-service (CDoS) attacks.
- China continues its quest for cyber sovereignty, with aggressive new measures to nationalize its own big tech companies.
- China's panopticon will spread beyond its geographical borders this year.
- The Biden administration appointed a wide slate of well-known scientists to key positions in the federal government and designated the head of the Office of Science and Technology Policy as a Cabinet-level position. Evidence-based science is back.



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**CDoS:**
When a company denies one or more users, businesses, or governments the ability to access its platform or services, this is an example of what the Future Today Institute calls a CDoS, a corporate denial-of-service (CDoS).



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4TH YEAR ON THE LIST

# Antitrust Action

U.S. Sen. Amy Klobuchar (D-Minn.) is the incoming antitrust chair.

KEY INSIGHT

**U.S. antitrust laws ensure and promote fair competition between companies for the benefit of consumers. A move to break up big tech companies Apple, Facebook, Google, and Amazon has galvanized rare bipartisan support. In 2021, the Biden administration will pursue a number of lawsuits targeted at America's tech giants.**

EXAMPLES

Outside the U.S., regulators plan to limit the world's largest tech companies' reach and power. Lawmakers and federal agencies express 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, which has helped powerful tech interests consolidate even more power. Incoming antitrust chair U.S. Sen. Amy Klobuchar (D-Minn.) argues that today's antitrust laws don't work in the age of big data and algorithmic decision-making. Expect in 2021 to see increased funding for the U.S. Federal Trade Commision and Justice Department, renewed investigations of market dominance, new scrutiny of acquisitions and control of user data, and new lawsuits that aim to decouple WhatsApp and Instagram from Facebook.



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# Antitrust Action continued

Facebook faces antitrust action in 2021.

## DISRUPTIVE IMPACT

The Biden administration may expand the scope of investigations against Google, Amazon, Facebook, and Apple, while pursuing stricter enforcement of mergers. But existing antitrust laws don't always mesh with our ever-evolving business landscape. For example, Amazon's acquisitions of Zappos, Diapers.com, and Whole Foods expanded the company's overall retail footprint significantly, but the acquisitions do not amount to unfair competition in their respective markets. (By contrast, one could not make the same argument if Walmart bought Publix and Safeway.) 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 being really, really smart. The European Union's Digital Services and Markets Acts will require tech giants to protect consumers against illegal goods and counterfeits and will 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, executive vice president of the European Commission's A Europe Fit for the Digital Age
- U.S. Sen. Amy Klobuchar (D-Minn.)
- Rohit Chopra, former FTC commissioner (and proposed Consumer Financial Protection Bureau Commissioner as of this writing)
- Lina Khan, Columbia Law School professor and antitrust expert
- U.S. Department of Justice's Antitrust Division



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1ST YEAR ON THE LIST

# States Unite Against Big Tech

New York Attorney General Letitia James is leading a lawsuit against Facebook for anticompetitive business practices.

## KEY INSIGHT

**State governments are taking action on their own, filing antitrust lawsuits against the tech giants.**

## EXAMPLES

On Dec. 17, 2020, attorneys general from 38 states filed antitrust lawsuits against Google, alleging that the company's search results favor its own services and arguing it used its dominance to become the default search engine across nearly all digital devices, including web browsers, smartphones, connected cars, and connected home appliances. Just one day earlier, a separate multistate lawsuit was filed against Google accusing the company of misleading, false, or deceptive acts through its Google Ads auction process. Many of these very same states also filed lawsuits against Facebook, alleging that the company bought competitors such as Instagram and WhatsApp in an aggressive, predatory manner.

## DISRUPTIVE IMPACT

Companies that have typically benefited from gridlock at the federal level may find themselves in lawsuits against a coalition of attorneys general. These AGs have the authority to sue for violations of both state and federal antitrust laws. While these lawsuits may take years to unfold, mounting pressure from state AGs could give a Democratic-controlled federal government the ammunition to update antitrust laws. Current antitrust laws were written to protect consumers from unfair pricing. The big tech companies have far broader power, controlling the news we read, the ads we see, and sometimes even how we see ourselves.

## EMERGING PLAYERS

- U.S. Sen. Amy Klobuchar (D-Minn.)
- Anindya Ghose, antitrust expert witness and professor at the New York University Stern School of Business
- Letitia James, New York attorney general
- Lina Khan, Columbia Law School professor and antitrust scholar
- Timothy Wu, Columbia Law School professor and antitrust scholar



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# Scenarios

## Predictive Legislation

### Near-future optimistic scenario

Government is using predictive artificial intelligence to better understand gaps in the legal system, especially with regard to the repercussions of emerging technology. Rather than waiting for court cases and lawsuits to set legal precedents for the use—and abuse—of technology, the algorithms anticipate conflicts and preemptively design future laws. We run simulations for outliers in human behavior, hacks, subversions, misinterpretations, and more. These exercises allow policymakers to work with the best available data instead of perpetuating a flawed system of loopholes, and constantly playing catchup with the latest tech. Predictive law is a new field that, if applied wisely, eliminates the risks inherent in the backward-looking legal models of the past.



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1ST YEAR ON THE LIST

# Cloud Neutrality

Amazon's decision to shut down Parler shows how much influence cloud companies have 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 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. Cloud services account for a significant amount of quarterly earnings: $9 billion for Alphabet (Google Cloud), $10 billion for Amazon Web Services (AWS), and $12 billion for Microsoft. It can take several years for a large company to integrate its data with a cloud, making selection a high-stakes choice. Netflix's 2009 selection of AWS was a big deal—before Amazon Prime Video existed. What if a cloud provider offers preferential treatment to its own services over the competitor it's hosting? The cloud isn't public infrastructure; it's private.

## DISRUPTIVE IMPACT

Following the attack on the U.S. Capitol, AWS kicked Parler, the ultraright social platform, off its cloud for violating its terms of service. The move unilaterally and swiftly dismantled the platform. The decision by Amazon shows how much influence cloud companies have over the internet. Molly Wood, the senior editor of NPR's "Marketplace Tech," likens the consolidation of power among cloud providers to that of internet service providers (ISPs), which both own the infrastructure and the means to throttle access to the internet. Advocates for net neutrality argue that ISPs shouldn't be able to control how we access digital services, including the internet. Wood argues that access to the cloud is analogous, and that it's time we start talking about cloud neutrality.

## EMERGING PLAYERS

- AWS
- Microsoft Azure
- Google Cloud
- U.S. Federal Trade Commission
- U.S. Federal Communications Commission



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2ND YEAR ON THE LIST

# Digital Border Clashes

When COVID-19 forced schools to close, not all students had equal access: Those in urban areas could connect to the internet for remote learning, but those in rural areas struggled.

## KEY INSIGHT

**Digital technology was supposed to increase opportunity and create open access to information. But varying regulation and broadband access across geographies give internet users (and data) different rights in different places.**

## EXAMPLES

The pandemic threw the geographic digital divide into stark relief because so much of life shifted online. Those who could connect continued to socialize, participate in local government hearings, and access the broader world; those who couldn't connect were isolated. The New York City Department of Education sent hot spot–enabled iPads to families that couldn't afford an internet connection, while students in Appalachia, the Navajo Nation Reservation, and other rural areas got lessons asynchronously through USB drives, on school buses with hot spots, or on a hilltop with spotty cell service—or they didn't learn at all. Pre-pandemic, internet users' protections varied based on their locations. Californians, for instance, get GDPR-style rights to have information deleted; residents in other states don't have that right.

## DISRUPTIVE IMPACT

President Joe Biden and the Democrat-controlled Congress may introduce regulations that potentially upend ad-supported revenue models. Watch for major changes to any business practices, such as subscription marketing tactics, that depend on consumer data. Watch, too, whether the G-MAFIA (Google, Microsoft, Amazon, Facebook, IBM, and Apple) influences legislators to shape the process or whether the debate focuses on punishing Big Tech. Without coordinated effort, geographic differences in rights and expectations will proliferate, changing economics and operating models for companies with international customers (or customers in various U.S. states). Established tech platforms and multinational organizations can handle that kind of regulatory complexity, but it may be tough for new entrants to serve—and monetize—audiences in multiple jurisdictions. Consent management platforms like OneTrust and Quantcast will gain more power in the marketplace.

## EMERGING PLAYERS

- OneTrust
- Quantcast



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1ST YEAR ON THE LIST

# State Governments Tackle Digital Privacy

The CCPA marked the first data privacy law to come into effect in the United States.

## KEY INSIGHT

**As the federal government stalls on delivering meaningful data privacy protections, state governments are taking action.**

## EXAMPLES

The California Consumer Privacy Act (CCPA) went into effect in early 2020 and became the first set of data privacy laws in the United States. It affords California residents the right to know about personal information collected, the right to delete personal information collected, and the right to opt out of the sale of their personal information. State legislatures in Hawaii, Massachusetts, New York, and Washington have introduced similar bills, indicating that blue states are ready to advance data privacy rights. In August, 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. In 2020, Vermont Attorney General T.J. Donovan filed suit against Clearview AI for violating the state's data broker laws.

## DISRUPTIVE IMPACT

Hope is not lost, despite Washington, D.C., gridlock. 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. Democrats, with control of the U.S. Senate, may spearhead national data privacy regulations. 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 early 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

- K. Dane Snowden, president and CEO of the Internet Association
- T.J Donovan, Vermont attorney general
- U.S. Sen. Maria Cantwell (D-Wash.)
- U.S. Sen. Richard Blumenthal (D-Conn.)
- New York State Sen. Kevin Thomas
- Signal



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2ND YEAR ON THE LIST

# Regulating Data Ownership

Solid lets people securely store their data in decentralized data stores.

## KEY INSIGHT

**Who exactly owns the rights to consumer data? Who can control it? Tech companies, advocacy groups, and governments are grappling with who has ultimate power and control over information.**

## EXAMPLES

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. Former U.S. presidential candidate Andrew Yang, the World Economic Forum, and the United Nations each aim to create guidelines for data ownership, while the proposed Own Your Own Data Act would declare that each person owns their online data and has exclusive property rights to it, and that social media companies must obtain licenses to use it. A bill drafted by Sens. Josh Hawley (R-Mo.) and Mark Warner (D-Va.) would require Facebook, Google, and Amazon to disclose the monetary value of the personal data collected.

## DISRUPTIVE IMPACT

The regulatory scrutiny of Big Tech focuses on antitrust concerns and privacy, but larger questions loom: 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 your genetic data? If a consumer takes a 23andMe DNA test, who owns her genome? What happens to consumers' enormous trails of data when they die—who has the rights to inherit it or terminate its use?

Determining what can be done with that data, and under what circumstances, should be a topic of conversation in every boardroom. Data governance may sound boring, but it should be a centerpiece of every corporate strategy.

## EMERGING PLAYERS

- Sir Tim Berners-Lee's Solid initiative
- California Consumer Privacy Act
- CitizenMe
- MIT Trust-Data Consortium

> In a digital economy, data is currency.



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## You're Saddled with Data Debt

**Mid-future catastrophic scenario**

Tech companies take a page from today's banks, which earn more profit the more consumers carry debt. Just as bank customers can become hopelessly buried in financial debt, consumers can find themselves drowning in "data debt," committed to providing deeper levels of personal data in exchange for indispensable services. Eventually, your every thought and action is quantified, seized, and made available for sale by the new debt collectors of the tech sector.


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2ND YEAR ON THE LIST

# Interoperability Initiatives

U.S. Sen. Mark Warner (D.-Va.) leads a bipartisan effort to make Big Tech's platforms interoperable.

### 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. New initiatives pushing for common standards are moving ahead in 2021.**

### EXAMPLES

Zigbee Alliance is developing a shared connectivity standard allowing hardware from different companies to work together. Amazon, Apple, and Google are members, but their devices don't work across platforms yet. Meanwhile, a bipartisan group of lawmakers led by Sens. Mark Warner (D-Va.), Richard Blumenthal (D-Conn.), and Josh Hawley (R-Mo.) proposed a new bill to encourage competition by making Big Tech's platforms interoperable. The Augmenting Compatibility and Competition by Enabling Services Switching (ACCESS) Act would require Google and Facebook 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.)

### 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. 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

- Zigbee Alliance
- Dotdot
- National Institute of Standards and Technology



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# Expert Insight

## How the Pandemic Pushed Fast Advancements in the Public Sector

**Jeff Le**

U.S. State and Local Public Policy Lead for VMware

The pandemic upended the way governments, universities, and schools deliver citizen services and instruction. The silver lining: The future came faster for the public sector, which adopted flexible work arrangements, honed organizational culture, built stronger physical security, and implemented cybersecurity controls.

Consistent investment in technology and innovation has become a broadly recognized priority in the public sector. I see three areas that will continue to grow in importance: government technology modernization, sustainability, and workforce development.

### Government technology modernization.

State and local governments hemorrhaged amid the pandemic. Unemployment agencies and motor vehicle departments across the country failed to meet the demand of remote services and faced serious cybersecurity concerns. The FBI reported a spike in fraudulent unemployment insurance claims involving stolen personally identifiable information. For instance, California paid at least $400 million in unemployment benefit claims filed in the names of state prison inmates.

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> Multiple state governments are evaluating the use of blockchain technology to deliver services, and we'll see more digital infrastructure investments and cloud security strategies.

As a result of these failings, policymakers and politicians are interested in systems that reflect the 21st century. Multiple state governments are evaluating the use of blockchain technology to deliver services, and we'll see more digital infrastructure investments and cloud security strategies, amid more data breaches and growing calls for higher privacy standards such as those set forth by the California Privacy Rights Act of 2020.

### Sustainability.

The move to the cloud and stronger digital backbones could result in reduced emissions and lower energy costs. Companies and (most) governments recognize the importance of pursuing sustainability in operations in order to combat the climate crisis (or at least realize tangible cost savings). Less reliance on one central location may minimize disaster recovery challenges, should extreme weather events compromise a data center.

### Workforce development and diversity, equity, and inclusion.

Personnel is policy. Recruitment and retention posed the biggest challenge to technology companies during the pandemic, as they consolidated their influence and worked to capture global markets. The work from home policies resulted in longer hours and record productivity but also came at the cost of extensive burnout. There are significant morale challenges, and more must be done to focus on the personal growth of employees, rather than just pure output.

In addition, partnerships with government and higher education have delivered collaboration on cloud computing curriculum that was sorely needed at community colleges and promise to improve the meager diversity pipeline. Diversity is both a national security issue and a company culture imperative. Whether responding to a cyber event or creating an environment for working parents, companies and governments will become more resilient the more their teams reflect a broader and more inclusive range of experiences and backgrounds. The pandemic has highlighted some of these structural and institutional legacy inequities.

**

*Jeff Le (@JeffreyDLe) is U.S. state and local public policy lead for VMware. He was deputy Cabinet secretary to former California Gov. Jerry Brown and oversaw technology issues, economic development, homeland security and statewide cybersecurity, and government operations.*



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1ST YEAR ON THE LIST

# Science Is Back

Eric Lander was nominated to lead the OSTP.

## KEY INSIGHT

**The Biden administration is elevating famed scientists to key positions in the federal government, signaling a return to evidence-based research and forward-leaning policymaking.**

## EXAMPLES

One of the first announcements made by the Biden administration was a plan to make the White House Office of Science and Technology Policy (OSTP) a Cabinet-level agency, and it nominated geneticist and mathematician Eric Lander to lead the office. Lander, a biology professor at Massachusetts Institute of Technology and Harvard Medical School, was part of the public consortia that mapped the human genome. Elevating the position to the Cabinet marks a stark contrast to the Trump administration, which gutted the OSTP and waited nearly two years to nominate a director. In addition, Biden nominated two scientists—Maria Zuber, a planetary scientist and MIT's vice president for research, and Frances Arnold, a Nobel Prize–winning scientist who helped pioneer the synthesis of artificial proteins—to the President's Council of Advisors on Science and Technology.

## DISRUPTIVE IMPACT

Across the federal government, 20 agencies fund science. A Cabinet-level position will be uniquely positioned to coordinate these disparate groups for better research and data sharing, to gain insights, and to launch big, collaborative projects. Biden has already charged these scientists with challenging questions: What lessons does the pandemic offer on the nation's public health needs? What scientific advances are required to address climate change? How can the United States maintain technological and economic dominance? How can the administration nurture research and ensure that breakthroughs benefit all Americans? Answering these questions will undoubtedly unlock new funding, lead to public-private partnerships, and provide opportunities for startups across numerous industries—at least for the next four years.

## EMERGING PLAYERS

- Office of Science and Technology Policy
- President's Council of Advisors on Science and Technology

> Science will always be at the forefront of my administration—and these world-renowned scientists will ensure everything we do is grounded in science, facts, and the truth."
>
> — President Joe Biden



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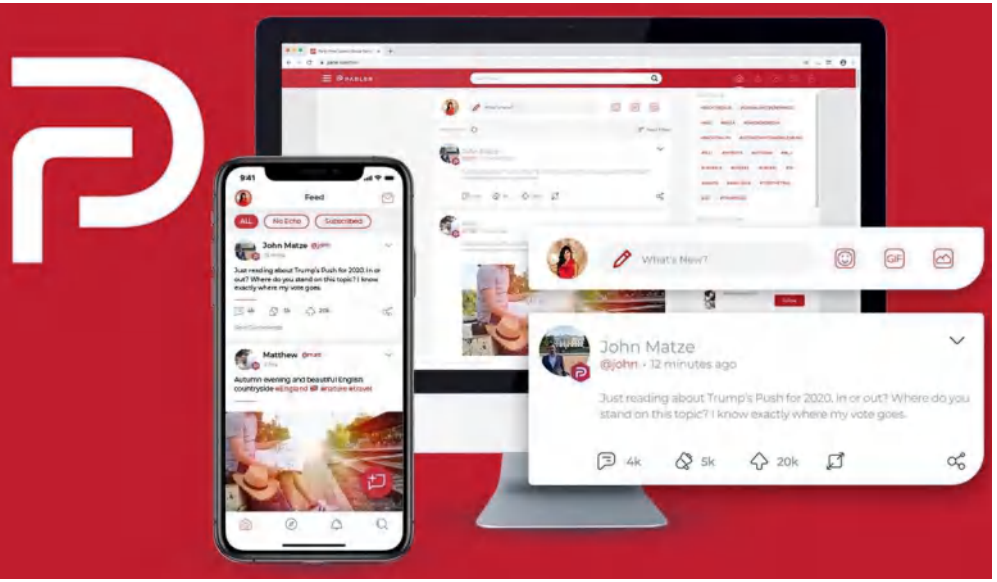
1ST YEAR ON THE LIST

# Corporate Denial-of-Service (CDoS)




AWS removed Parler for violating Amazon's terms of service.

## 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 what the Future Today Institute calls a CDoS, a corporate denial-of-service.**

## EXAMPLES

In the aftermath of the U.S. election, when former President Trump spread lies about votes being rigged or miscounted, conspiracy theorists and right-wing activists used social media to spread misinformation. This led to tech platforms taking action to suspend or deactivate accounts. On Jan. 6, 2021, Trump delivered a fire-and-brimstone speech calling for decisive, violent action. Some followers complied, attacking the U.S. Capitol in a deadly insurrection. The next day, Facebook temporarily denied Trump the right to post from his account. 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 the oathkeepers.org, the site of the far-right militia group. Deplatforming worked: Weeks later, conversations about election fraud decreased on the largest platforms.



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# Corporate Denial-of-Service (CDoS) continued

Twitter permanently banned President Trump after he incited a riot at the Capitol.

### DISRUPTIVE IMPACT

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. Platforms played a key role—and some argue that the steps taken to remove radical groups came too late. Some lawmakers argue that tech companies overreached. The fate of Section 230, the law that offers civil liability protections to platforms like Google, Facebook, and Twitter, was called into question at the end of 2020 when Sen. Josh Hawley (R-Mo.) proposed a bill requiring platforms to stop what he perceived to be the targeting of conservative commentary. Florida Gov. Ron Desantis proposed new laws that would impose daily fines of $100,000 if a platform restricts the speech of a candidate while running for a state office.

### EMERGING PLAYERS

- Rebekah Mercer, heiress and right-wing activist
- Mark Zuckerberg, CEO of Facebook
- Jack Dorsey, CEO of Twitter
- U.S. Sen. Josh Hawley (R-Mo.)

Amazon's decision to CDoS Parler demonstrates the power the cloud provider has over the internet.



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2ND YEAR ON THE LIST

# Corporate Foreign Policy

In 2014, Google Chairman Eric Schmidt made a trip to Cuba, which presaged President Obama's announcement that Google would work with Cuba to speed up internet connectivity.

## KEY INSIGHT

**Big tech companies are standing up departments dedicated to geopolitics.**

## EXAMPLES

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. Microsoft President Brad Smith regularly meets with heads of state and foreign ministers about the tech cold war between America and China, emerging cyberthreats, and closing the digital divide in emerging markets. In 2017, Smith introduced a Digital Geneva Convention, an international treaty to protect citizens against state-sponsored cyberattacks. And Microsoft's Digital Diplomacy Group actively works on a tech-focused approach to foreign policy. The company sees corporate foreign policy as good business, because it builds trust and enables long-term planning. Apple, Google, and Amazon are building their own divisions centered on geopolitics and digital diplomacy.

## DISRUPTIVE IMPACT

As they consolidate power in the commercial sector, Big Tech could wind up consolidating power in the public sector, too. It's one thing for a big company to lobby domestic lawmakers. Some now ponder the longer-term implications if corporations try to influence geoeconomics. What if a company's priorities differ from the national priorities of its government at home?

## EMERGING PLAYERS

- Microsoft's Digital Diplomacy Group
- Facebook for Government, Politics, and Advocacy
- Jigsaw
- Google's Business Strategy Division
- Amazon's Public Policy teams
- Office of Science and Technology Policy



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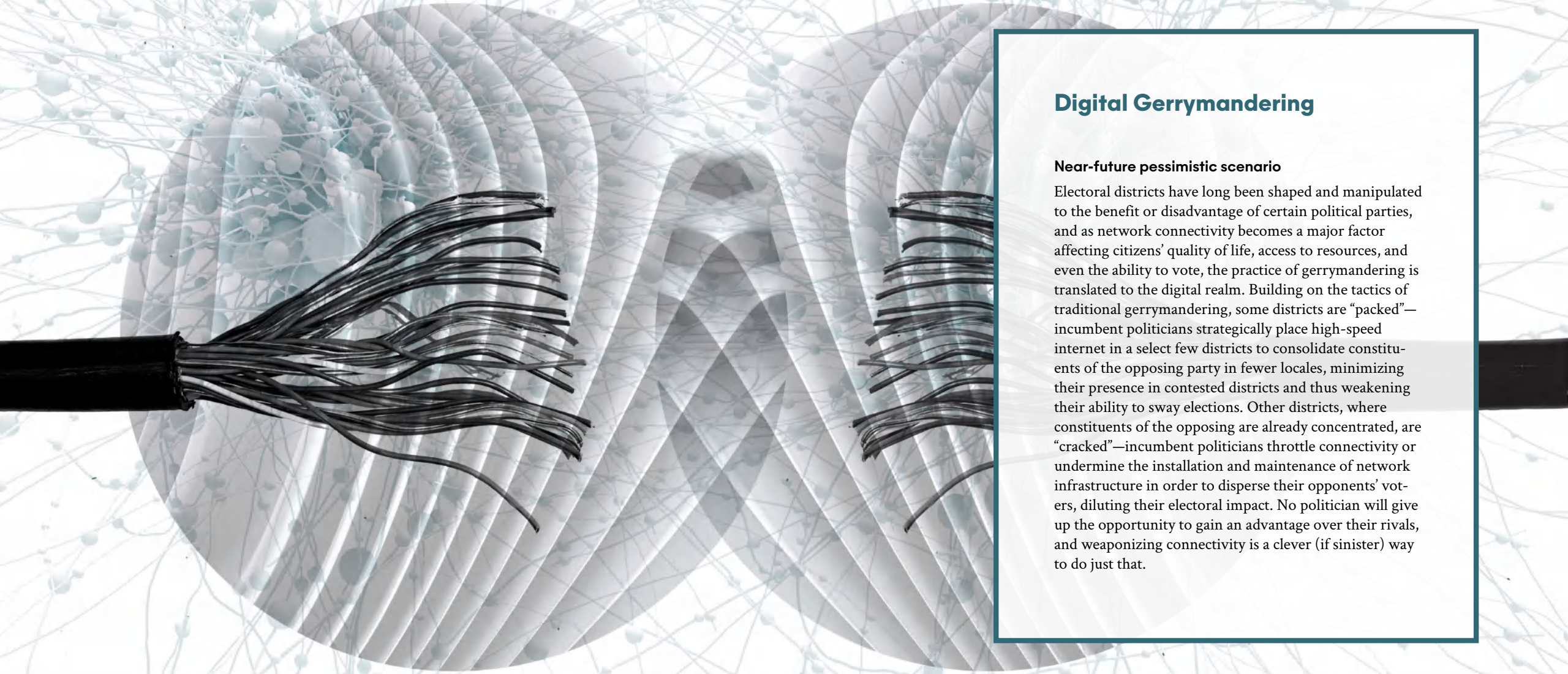

## Digital Gerrymandering

**Near-future pessimistic scenario**

Electoral districts have long been shaped and manipulated to the benefit or disadvantage of certain political parties, and as network connectivity becomes a major factor affecting citizens' quality of life, access to resources, and even the ability to vote, the practice of gerrymandering is translated to the digital realm. Building on the tactics of traditional gerrymandering, some districts are "packed"—incumbent politicians strategically place high-speed internet in a select few districts to consolidate constituents of the opposing party in fewer locales, minimizing their presence in contested districts and thus weakening their ability to sway elections. Other districts, where constituents of the opposing are already concentrated, are "cracked"—incumbent politicians throttle connectivity or undermine the installation and maintenance of network infrastructure in order to disperse their opponents' voters, diluting their electoral impact. No politician will give up the opportunity to gain an advantage over their rivals, and weaponizing connectivity is a clever (if sinister) way to do just that.

# Scenarios



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2ND YEAR ON THE LIST

# Techno-Nationalism

Technology shapes the global balance of power.

## KEY INSIGHT

**In the digital age, a nation's technology capabilities are inextricably linked to its economic prosperity, national security, and social stability. Technology shapes the ways the countries relate to one another, and it influences the global balance of power.**

## 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, AI, 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 the state in everyday life.

## DISRUPTIVE IMPACT

China's new Foreign Investment Law imposes strict rules for vetting foreign investments on national security concerns. Widely seen as retaliation for the 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 under Trump 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
- China's Foreign Investment Law



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5TH YEAR ON THE LIST

# Splinternets

A military junta shut down Myanmar's internet in 2021.

## KEY INSIGHT

**The founding promise of the digital world was broad connectivity where information could flow freely. But as some governments take steps to filter (or completely block) access to the internet and subscription models make wealth a prerequisite for access to reliable information, we're headed toward a fragmented future with "splinternets" rather than a single world wide web.**

## EXAMPLES

Nation-scale internet censorship is most closely associated with China's "great firewall." The Chinese government aggressively monitors the internet and removes information that doesn't meet its political standards. 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: "We should respect the right of individual countries to independently choose their own path of cyber-development," said Chinese President Xi Jinping at China's second World Internet Conference in 2015. 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 virtual private network (VPN) to reach unfiltered information—or a financial one.

## DISRUPTIVE IMPACT

The playbook for governments dealing with social unrest increasingly includes trying to disrupt the digital tools activists use to organize. If it becomes clear that leaders can follow that playbook with impunity, look for it to be increasingly adopted by democratic governments. Early this year, 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 VPNs couldn't bypass the blackout. India shut down phone and internet services to protesters several times in 2020, and instituted new bans in February to de-escalate protests.

## EMERGING PLAYERS

- Freedom House
- Amnesty International
- Access Now



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1ST YEAR ON THE LIST

# Vaccine Nationalism

A rise in vaccine nationalism resulted in poorer nations being unable to secure doses.

## KEY INSIGHT

**While options for effective COVID-19 vaccines emerged by late 2020, capacity met only a fraction of the global demand. Weak cooperation between businesses and countries caused an imbalance over which citizens got access to the vaccine.**

## EXAMPLES

In 2020, wealthy nations pre-ordered 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. (That's not 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.

## DISRUPTIVE IMPACT

At a virtual meeting of the World Economic Forum in January 2021, South African President Cyril Ramaphosa pleaded with wealthy nations to share their doses. As he gave his speech, a dangerous coronavirus mutation known as 501Y.V2 was spreading: It seemed to be more transmissible, and possibly more resistant to antibody therapies. And it emerged in South Africa. We risk splitting our countries, and our communities, into biological haves and have-nots. Covax, a vaccine sharing fund, began offering its first doses in February, but it still had to compete with nations such as the U.K. and U.S. that could afford higher prices to secure what limited supplies were available. The director-general of the World Health Organization warned of a "catastrophic moral failure" if rich nations continued to hoard doses.

## EMERGING PLAYERS

- World Health Organization
- Covax

> We risk cleaving our countries, and our communities, into biological haves and have-nots.



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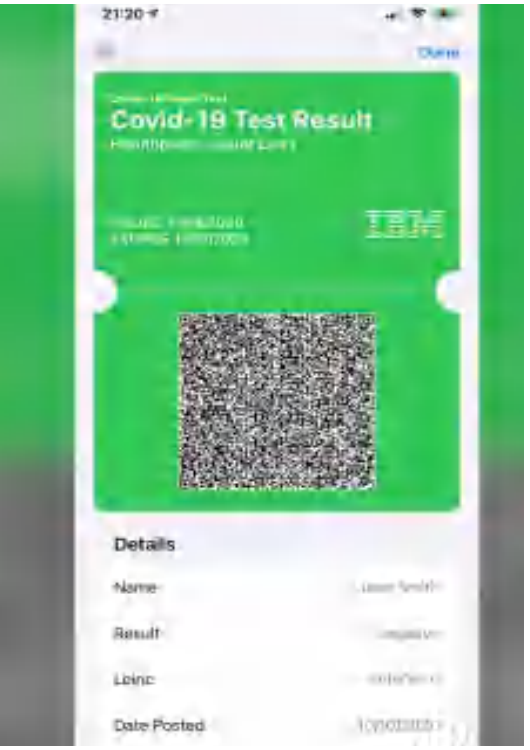
1ST YEAR ON THE LIST

# Vaccine Passports




Tech companies such as IBM are developing digital vaccine passports or mobile wallets for test results.

## KEY INSIGHT

**Different countries began requiring proof of a COVID-19 vaccine at borders in 2021. Big tech companies are working to build digital identification systems that function as vaccine passports.**

## EXAMPLES

Restaurants, sports arenas, entertainment facilities, and tourist destinations continue to bleed money with Covid lockdowns; tourism-dependent countries are understandably eager to reopen their borders. Several countries, including Romania, Cyprus, and Seychelles, lifted quarantine restrictions for travelers with proof of inoculation. The United Nations World Tourism Organization called for the global adoption of vaccination passports using a single standard, not unlike traditional passports that allow people to travel between borders.

## DISRUPTIVE IMPACT

Several vaccine passport systems are underway. The Geneva-based Common Trust Network, a project supported by the World Economic Forum, developed a secure mobile app that lets users upload official Covid test results and proof of vaccination. The app generates a QR code with a health certificate to be shown to authorities without revealing personal information. Partners include U.S. health systems and several airlines (United Airlines, JetBlue, Lufthansa, Swiss International Air Lines, Cathay Pacific, Virgin Atlantic). IBM developed the Digital Health Pass, an adaptation of a digital wallet. Companies can customize the criteria required for entry (proof of vaccination, as well as Covid tests and other biometrics). Because competing credentialing systems will be a problem, the COVID-19 Credentials Initiative is working to develop a set of common standards for vaccine passports.

## EMERGING PLAYERS

- Linux Foundation Public Health
- COVID-19 Credentials Initiative
- Clear
- CommonPass
- IBM
- United Nations World Tourism Organization



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1ST YEAR ON THE LIST

# City-Scale Digital Twins

City-scale digital twins will shape our future urban landscapes.

## KEY INSIGHT

**Cities are using digital twins of themselves to model the interplay of real-world infrastructure, topography, movement, and population. The result: better management in the real world.**

## EXAMPLES

Building on cities' traditional modeling tools, these digital twins draw on data from intelligent buildings, vehicles, and infrastructure to help decision-makers play out a variety of scenarios. They can prepare emergency management for events like floods and power outages,

and they can assess the impact of a construction project, such as the shadow it casts on nearby properties or how it affects traffic flow. The first digital twin city, Virtual Singapore, locates areas that need better mobile data coverage, models barrier-free routes for people with disabilities, and identifies buildings ideal for solar panel installations. Sydney made its digital twin an open-source platform to better plan for land development.

## DISRUPTIVE IMPACT

As cities worldwide develop digital twins, they will combine historically siloed and buggy datasets from many sources. As a result, city government vendor contracts will shift further toward data aggregation, cleaning, management, and analytics. Digital twins will eventually take over micro-decisions from city government, such as snowplow routing. Companies building artificial intelligence systems to predict, plan for, and respond to urban needs will see successes, as cities seek to streamline operations in perpetually budget-strained environments. Autonomous vehicle companies and buildings will enjoy the benefits of more and better data, such as 4D maps. Likewise, insurance companies will be further empowered to pinpoint risk areas based on intricate prediction models. Privacy concerns around using data that can identify individuals may limit the scope of some predictions.

## EMERGING PLAYERS

- National Research Foundation, Prime Minister's Office, Singapore
- Arup Group
- Siemens
- Taisei
- Dassault Systèmes



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1ST YEAR ON THE LIST

# State Charters for Blockchain

Wyoming legislators have been key in promoting a friendly regulatory environment toward crypto.

## KEY INSIGHT

**U.S. states are developing charters and special permissions to stimulate blockchain use for digital identification, cryptocurrencies, and managing digital assets.**

## EXAMPLES

In 2020, 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 November, the University of Wyoming launched its Center for Blockchain and Digital Innovation, signaling a growing trend in the state.

## DISRUPTIVE IMPACT

In 2015, Kraken and other crypto companies ceased operations in New York after the rollout of strict regulations. 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 in 2021. Miami Mayor Francis Suarez, who launched a Twitter campaign at the end of 2020 pitching the city as the next center for fintech innovation, met with crypto industry leaders and explored a Miami-based Gemini LATAM headquarters with founders Tyler and Cameron Winklevoss.

## EMERGING PLAYERS

- Avanti Bank founder Caitlin Long
- Wyoming Gov. Mark Gordon
- U.S. Sen. Cynthia Lummis (R-Wyo.)
- Andrew Yang
- Miami Mayor Francis Suarez



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1ST YEAR ON THE LIST

# State Laws for Facial Recognition

As the infrastructure for facial recognition technology expands, questions around unfettered surveillance remain.

## KEY INSIGHT

**States are developing local laws for facial recognition technology and its use in law enforcement.**

## EXAMPLES

In early 2020, New Jersey Attorney General Gurbir Grewal directed all police departments to cease the use of Clearview AI, a controversial facial recognition tool. Despite questions around accuracy, collection methodologies, and privacy rights, Clearview reportedly built a database of more than 3 billion photos scraped from the likes of Facebook and Venmo. Later in the year, a New Jersey man sued a local police department after a facial recognition tool mistakenly linked him to a shoplifting case and he spent 10 days in jail. A similar situation unfolded in Michigan, after police wrongly arrested a Black man due to mistaken facial recognition. A growing body of research found consistent inaccuracy when facial recognition algorithms attempt to identify females, people of color, and younger people.

## DISRUPTIVE IMPACT

While lawmakers introduce legislation to curb the use of facial recognition, infrastructure for the technology grows by the second as users upload photos and video to TikTok, Instagram, and other social platforms. Technology companies are aware of the problem: Last summer Microsoft and IBM banned the police use of their technologies, and Amazon placed a one year moratorium on police use of its Rekognition tool. However, facial recognition technology did aid in arrests made following the Jan. 6, 2021, U.S. Capitol riot. Lawmakers must grapple with privacy rights and unauthorized collection of data, as well as with the technology's effectiveness in law enforcement.

## EMERGING PLAYERS

- New Jersey Attorney General Gurbir Grewal
- New York State Sen. Brad Hoylman
- U.S. Sen. Ed Markey (D-Mass.)
- U.S. Department of Justice
- American Civil Liberties Union



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3RD YEAR ON THE LIST

# Multilateral Science and Technology Acts

COVID-19 has been a stress test of current cooperative relationships worldwide.

## 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

Multilateral agreements between sovereign nations resulted in the Geneva Conventions, League of Nations, International Monetary Fund, United Nations, and World Health Organization. Now, following revelations that a pair of genetically engineered twin girls was born in China, some wonder whether international norms are enough. As many fields of science and technology produce striking new developments, lawmakers, researchers, and ethicists are calling for some kind of consensus—and international deliberations that could lead to international treaties and protocols.

## DISRUPTIVE IMPACT

COVID-19 has been a stress test of current cooperative relationships worldwide. Throughout 2021, the outcome of vaccine distribution will result in vaccine nationalism or multilateralism, and that will have downstream effects on other key areas of science and technology—CRISPR, ocean plastics, climate, autonomous vehicles, AI, and space exploration—for years to come.

## EMERGING PLAYERS

- International Union of Biological Sciences
- United Nations
- World Health Organization



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5TH YEAR ON THE LIST

# Digital Dividends

A UBI program in Maricá, Brazil, launched in 2013.

## KEY INSIGHT

**A digital dividend would give citizens a cut of the profits derived from their personal data.**

## EXAMPLES

Proponents of an unconditional guaranteed income for everyone within a country argue that it would be a means of encouraging entrepreneurial innovation and that it would help offset the effects of automation, advanced robotics, and artificial intelligence on the market for human labor. California Gov. Gavin Newsom proposed a digital dividend that would allow state residents to share in the profits of big tech companies. There are already city-scale experimental universal basic income (UBI) programs running in Oakland and Stockton, California. The Stockton project initially gave 125 randomly selected low income families $500 a month for 18 months; recipients spent the money on utility bills, credit card debt, groceries, and dental work. The program, deemed successful, was extended into 2021.

## DISRUPTIVE IMPACT

With rising unemployment and financial loss, COVID-19 gave UBI programs new momentum. Germany launched a new UBI program in August 2020 similar to the Stockton experiment: 120 Germans are receiving 1,200 euros ($1,430) every month for three years. Researchers are comparing the UBI group with a control group not receiving basic income, to determine the impact on everyday life. Spain launched a UBI program for its lowest-income families and is distributing 1,015 euros ($1,145) to those in need. Kenya's UBI program, the largest and longest-running UBI experiment in the world, is five years into a 12-year experiment period. More than 20,000 people receive monthly payments, no strings attached.

## EMERGING PLAYERS

- Centre for Public Impact
- GiveDirectly
- California
- German Institute for Economic Research
- Renda Básica de Cidadania program in Brazil
- Stanford Center on Philanthropy and Civil Society



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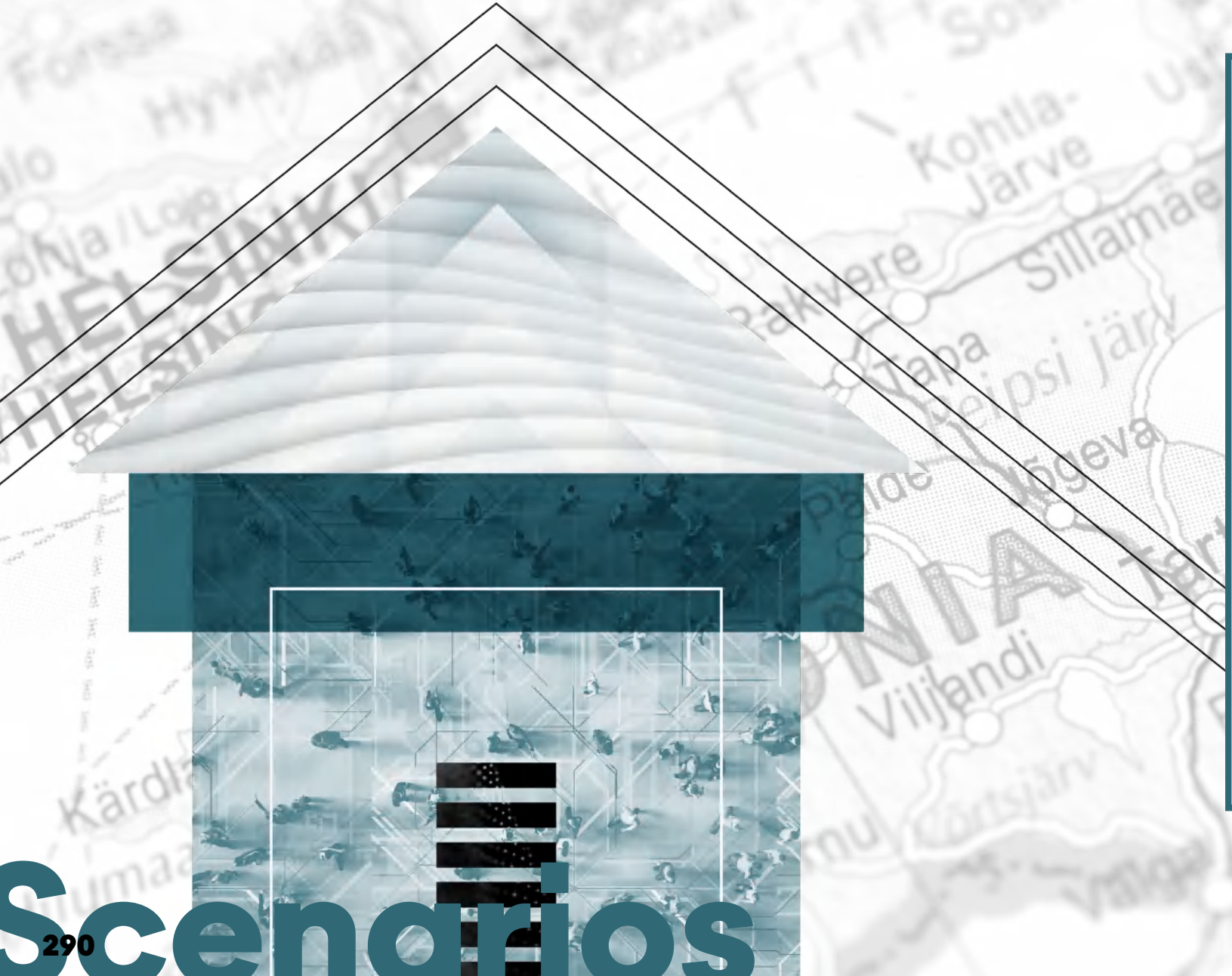

# Scenarios

## Citizenship Hedging

### Mid-future neutral scenario

E-residency is a system originally piloted in Estonia that allows globally itinerant or location-independent business owners and entrepreneurs to avail themselves of certain national services and resources in a foreign country without being a citizen there. As similar programs popped up across the globe, e-residency became a popular method to seek safe haven for companies in potential conflict zones. With mounting problems like political destabilization and climate change, securing e-residency abroad proved a valuable insurance policy for one's business—or even one's own well-being. Participating countries allow e-residents to take up physical residence for a limited period of time, if necessary, and while e-residency doesn't secure citizenship, it can improve your chances of moving up the immigration list. Not a bad option for those who don't have a bunker in New Zealand to escape to.



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5TH YEAR ON THE LIST

# Legacy IT Infrastructure

Government systems still run legacy IT equipment and software.

## KEY INSIGHT

**Parts of the federal government rely on comically old technology, which is very difficult to maintain. However, overhauling the infrastructure has bipartisan appeal.**

## EXAMPLES

In 2020, millions of people tried to file unemployment claims, and registration systems in 19 states crashed under the stress. Many systems haven't been updated since they were built in the 1980s. A desperate New Jersey Gov. Phil Murphy held a press conference pleading for volunteer COBOL programmers to help fix the state's automated benefits system. It took five months to issue $1,200 stimulus checks to eligible taxpayers because the Internal Revenue Service computer systems, built in the 1970s, couldn't be easily reconfigured. The U.S. government wastes $80 billion each year due to obsolete technologies and inefficiencies, according to a 2016 U.S. Government Accountability Office report. That sobering tech audit found that the State Department tracks visa information for 55,000 foreign nationals using a 26-year-old system that's been decommissioned by the software maker.

## DISRUPTIVE IMPACT

Fixing legacy systems is a technological as well as cultural challenge. Upgrading a legacy system that's critical for day-to-day operations would cause major disruption, and government offices, already strapped for personnel, don't have easy workarounds. And 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. Legacy systems are also vulnerable to attack.

## EMERGING PLAYERS

- U.S. Government Accountability Office
- United States Digital Service
- Office of Management and Budget
- Office of Science and Technology Policy



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2ND YEAR ON THE LIST

# China's Quest for Cyber Sovereignty

Chinese President Xi Jinping wants his country to be technologically independent this decade.

## KEY INSIGHT

**Cybersovereignty 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

In 2019, Chinese President Xi Jinping pushed forward an agenda of strict control, censorship, and suppression, and the country began exporting its systems to authoritarian leaders elsewhere in the world. And last year, provocative crackdowns on Hong Kong by the Chinese Communist Party (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. In January 2021, the CCP announced plans to nationalize Alibaba and Ant Group, two of China's most successful big tech companies.

## DISRUPTIVE IMPACT

The CCP 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. But there's more to it than that: In 2019, Xi also announced that the government would wean itself off foreign-made computers and operating systems, replacing familiar brands (Microsoft, Dell, Apple) with Chinese products. Xi has said China's digital and information systems can serve as a new model for other countries around the world and that other authoritarian 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

- Ant Group
- Alipay
- ByteDance
- Ren Zhengfei, Huawei founder
- Lei Jun, Xiaomi founder
- Pony Ma, Tencent founder
- Liu Chuanzhi, Lenovo founder
- Jack Ma, Alibaba founder



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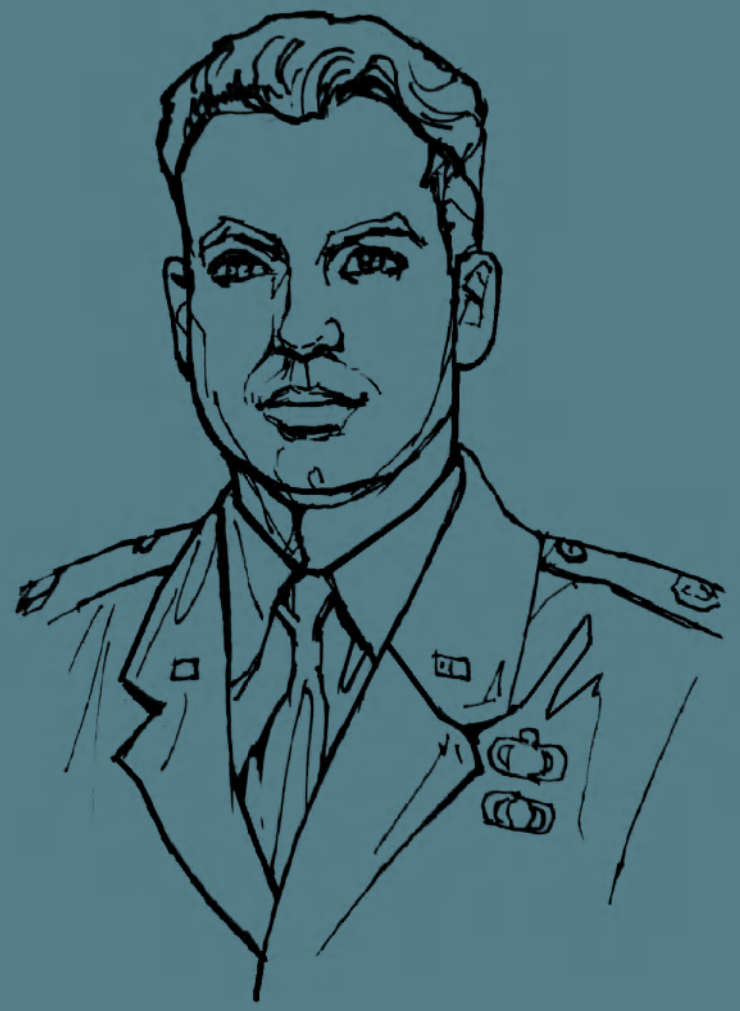
# Expert Insight



## The U.S. Defense and Space Future Will Require Flexibility and Adaptability

**Lt. Col. Jake Sotiriadis, Ph.D.**

Strategic Foresight and Futures Branch Chief

Headquarters, US Air Force

In 2021, a cycle of rapid change, growing complexity, and radical uncertainty will intensify the urgency for the national security establishment to become more adaptable to the unexpected. The COVID-19 pandemic revealed overlooked vulnerabilities for supply chains, our society, our economy, and our national security strategy.

The new strategic environment affects many of the baseline assumptions that underpin our national security strategy and service-level warfighting concepts. In light of these challenges, how can defense planners mitigate uncertainty?

Strategic foresight and futures thinking can lend insights into sources of disruption and disruptive technologies, by harnessing environmental scanning, weak signals, and emerging trend analysis. The security landscape of a post-Covid world contains both challenges and opportunities that will continue to defy accepted probabilities in defense.

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> Digital connectivity alone, however, will not be enough to prevail on tomorrow's battlefields or in tomorrow's boardrooms.

This includes the definition of what constitutes national security itself, which today must encompass non-traditional items, such as bio-security and advances in CRISPR technology. Signals and trends today also point to future developments in anticipatory health platforms that will be powered by quantum processors.

In 2021, disinformation is no longer limited exclusively to Russia, China, Iran, or violent extremist organizations. Rather, we are likely to see these actors waging simultaneous, multi-faceted influence campaigns on targeted populations at a global scale. These campaigns will continue to target all facets of our society.

We can expect to see increased defense partnerships with the technology sector—with traditional social media platforms as well as with startups developing emerging platforms to identify disinformation patterns. As we continue to focus on the competition among great world powers—with China and Russia as the primary threats to U.S. security—we also cannot lose sight of the new, emerging fault lines in the Middle East or complex crises on Europe's periphery.

Covid's disruption has also accelerated the export of China's worst characteristics, while prompting delays and disruptions to the country's Belt and Road Initiative. In the U.S. homeland, overly thin levels of inventory and long supply chains present risks to national security. The second and third order effects of Covid also increase the potential for more surveillance and automation in the name of public health—much as the terrorist attacks on Sept. 11, 2001, did for airport security procedures.

In the space domain, expect a targeted set of strategies to ensure the immense progress made in the commercial space industry over the past two decades is not lost. The need to accelerate space programs and transform capabilities in a fiscally constrained environment will feed investment in a technology pipeline, spur agile contracting, and strengthen partnerships with the commercial sector and international partners. This approach will alleviate weak supply chains, leverage cutting-edge technologies, and strengthen gaps in areas that require international cooperation (such as debris mitigation, space traffic control, and behavioral norms).

Military and national security entities will be consumed with networking their forces and trading information and data. This means moving toward cloud-based solutions that enable instantaneous



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sharing of information—delivering decision advantage within a rapidly shifting security environment. Efforts to transition legacy platforms toward new digital solutions will accelerate.

Digital connectivity alone, however, will not be enough to prevail on tomorrow's battlefields or in tomorrow's boardrooms. Advances in automation for the defense workforce will present a major dilemma in defining new skill sets that ensure contextualized knowledge remains—even in human-in-the-loop scenarios.

Maximizing human capital will require creating, enhancing, and developing our *cognitive operating system*.

**Here, we refer to a disciplined way of:**

1. **Questioning our assumptions**
2. **Seeing the interconnectivity of events**
3. **Embracing analytic complexity in our strategic planning**

Doing so requires both crafting and proliferating better methodologies for anticipatory thinking.

Digital solutions are necessary—but not sufficient—for success in retaining decision advantage. Seizing and occupying the cognitive high ground in the national security arena means more than just "buying things," developing weapons systems, or increasing technological leverage. It means also ensuring that professionals are given powerful technological tools with the requisite cognitive capacity for sense-making.

Last year was a critical one for digital transformation across all sectors, but make no mistake—2021 will be a year when companies seek increasingly innovative means to derive value chains from technology. It will be a year in which intentional strategies are indispensable to achieving success. In national security, defense, and the corporate world, organizations cannot simply "stumble" into tech solutions (as was the case in many instances in 2020). Absent a deliberate strategy and a clear road map for implementation, even the most advanced or disruptive technologies will not be a panacea.

**

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The views expressed in this section are those of the author and do not reflect official positions or endorsements of the U.S. Air Force or the Department of Defense.



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# Application

## STRATEGY

The intersection of technology, policy, and politics affects every business. 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. Chief strategy officers should work closely with chief technology officers and others in their organizations to develop near-term plans. Ongoing tensions between China and the U.S. will continue to impact the supply chain, intellectual property, and trade.

## INNOVATION

Policy uncertainty creates all sorts of hurdles for innovation teams. However, the Biden administration has taken office with 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 systems that use biometric recognition.

## R & D

China has emerged as an R&D powerhouse. In recent years, China has launched new programs to repatriate researchers from their U.S. and European posts. The Thousand Talents initiative bestows lavish packages—high salaries, luxury apartments, automatic admission to the best schools for children of researchers—to those who are willing to bring their expertise home. 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.

## RISK

China's Belt and Road Initiative, which has been a huge success in expanding trade throughout emerging economies, has also been a boost for the country's digital initiatives. As China pursues its cyber sovereignty plan, our existing splinternet will worsen. This will challenge foreign businesses that operate in China, spark new cybersecurity challenges, and eventually prevent some companies from reaching the Chinese market. Risk models should be developed to determine plausible near-future scenarios so that leaders can adjust their strategies accordingly.



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# 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 about technology, science, and policy:

1

Is our company's government affairs team proactive enough—or is it simply responding to policy changes?

2

What parts of our business make us vulnerable to state, national, or international government action?

When was the last time we audited the systems that keep those parts of our business safe?

3

Is our government department adequately planning for the longer-term? What assumptions must hold true for our current strategy to succeed? How will we make needed changes?



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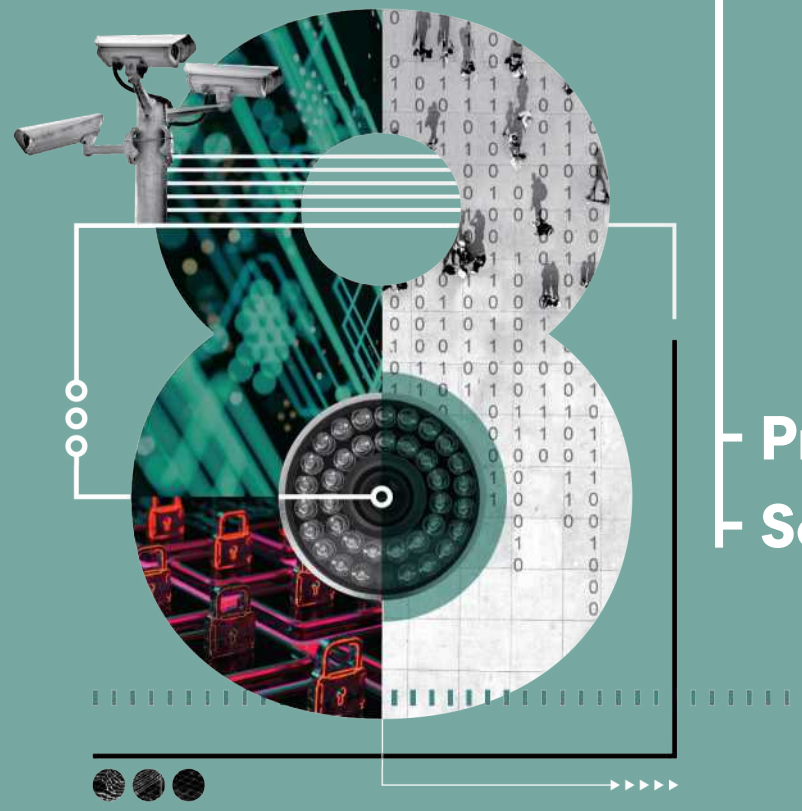
Volume 8 of 12

14th Annual Edition

# 2021 Tech Trends Report

Strategic trends that will influence business, government, education, media and society in the coming year.



## Privacy
## Security

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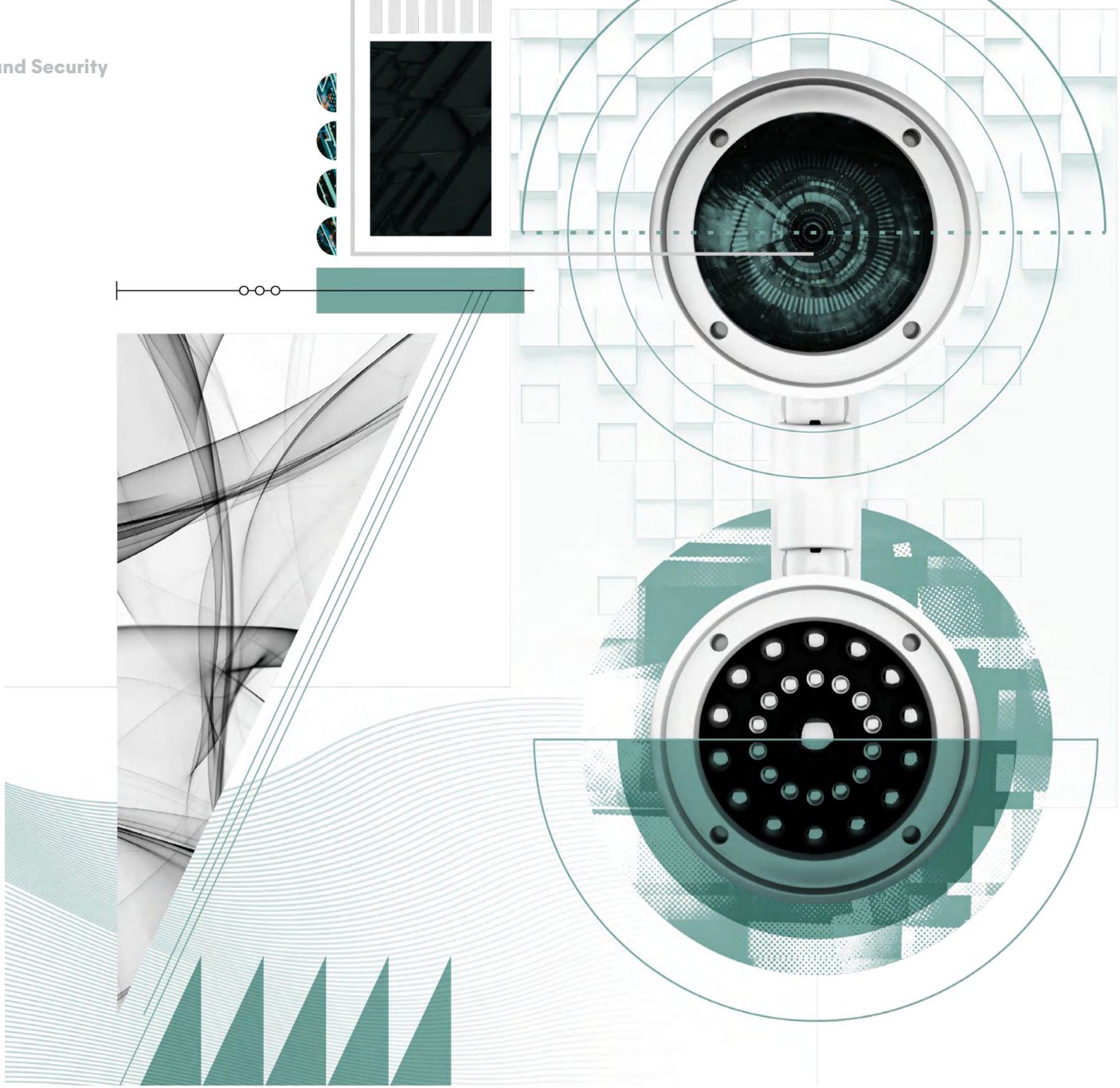

# Privacy & Security Summary

- COVID-19 accelerated the use of biometric data collection systems.
- Companies that allowed employees to work from home created new privacy and cybersecurity vulnerabilities.
- The attack on the U.S. Capitol led to an unprecedented amount of cybersleuthing—everyday people finding and posting the identities of insurgents online.
- There was a dramatic increase in Internet of Things scams and attacks, as hackers took advantage of employees and students working from their own devices and home networks, which are rarely secure.
- 75% of businesses do not involve their boards of directors in cybersecurity oversight.
- Cyberattacks cost the world economy an estimated $445 billion, or almost 1% of global income, according to the Center for Strategic and International Studies.
- Hackers increasingly look for sensitive intellectual property (business communications, vaccine code, DNA records).
- Cybersecurity risk areas this year include health care, pharmaceuticals, advanced materials and manufacturing, retail, municipalities, and military technology suppliers.



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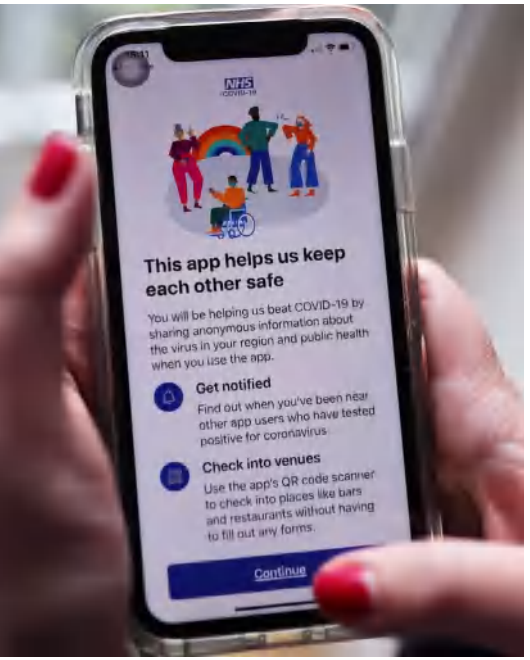
# Privacy

10TH YEAR ON THE LIST

# Privacy




The U.K.'s COVID-19 contact tracing app.

## KEY INSIGHT

**Data is one of a company's most important assets. Our modern economy relies on mining, refining, and making use of data, whether it comes from the supply chain or an individual's personal activities. Actively governing how data is collected, cleaned, shared, used, and stored is critically important.**

## EXAMPLES

COVID-19 pushed more activity online and accelerated measures to track and trace cases, but as a result, many countries relaxed data protections, increased biometric recognition, and forced citizens into location monitoring. The result: Untold volumes of personal information were exposed to the internet ecosystem. Prior to the pandemic, efforts were underway to curtail surveillance capitalism, thanks to the 2018 Cambridge Analytica scandal and the 2019 revelations that Clearview AI had scraped billions of images for a facial recognition database. Bipartisan privacy bills were underway, including one proposed by U.S. Sen. Kirsten Gillibrand (D-N.Y.) to create a new data protection agency—since the U.S. is one of the few democracies without one. The pandemic shifted priorities, and surveillance apps became key to get our economies humming again.

## DISRUPTIVE IMPACT

Industry-specific data privacy laws exist, such as the Gramm-Leach-Bliley Act, which requires financial institutions to safeguard consumer data, while the Health Insurance Portability and Accountability Act covers patient and personal health data. However, in the past few years, companies and government agencies have learned the hard way how important data privacy, transparency, and trust really are. Employers are requiring remote worker tracking software programs, schools are insisting on online proctoring and health tracking apps, and millions use Zoom, which for a while wasn't encrypted. This year, we will likely see fragmentation in privacy laws, as governments chase after big platforms (TikTok, Reddit, Snapchat, Twitter, WhatsApp, Facebook Messenger, Signal, YouTube) and ask them to disclose their data harvesting and sharing practices.

## 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
- BitSight
- Eclypsium
- ClearDATA
- BlackRidge Technology



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# Privacy Trends

**ProPublica, a nonprofit investigative news organization, published hundreds of videos posted to alt-right social network Parler. Screenshots from videos posted to Parler show the unfolding events at the U.S. Capitol on Jan. 6.**

Images courtesy of ProPublica.

## Trackers Everywhere

Nearly every website and mobile app contains some form of invisible tracking code that collects user data in order to build rich profiles for advertising. As invasive as that sounds, advertising revenue is what keeps the internet free. Outside of national governments, tracking companies house the biggest repositories of data. The data points collected are well beyond names and home addresses; companies know which emails you open, what steps you take after opening them, and whether you are likely to complete an online purchase. For now, tracking is only regulated in the European Union and California.

## Emphasizing Data Ethics

Consumers are increasingly aware that their data are being scraped and used, and they are starting to demand transparency. Companies should be prepared to explain the use, storage, and reselling of consumer data, and how consumer data could be used in the future. Just 6% of Americans believe their data are more secure today than in the past, while 62% don't believe it's possible to go through daily life without companies collecting data on them. At least 79%, however, are concerned about how companies use their data. If this doesn't sound alarming, consider the impact: 48% of consumers have stopped buying from a company over privacy concerns.

## Crowdsleuthing

Crowdsleuthing is the practice of internet users banding together, typically unbidden, in an attempt to solve mysteries and crimes (and occasionally take justice into their own hands). From assisting the authorities in identifying criminals to helping romantics track down missed connections, everyday people are rallying around investigative causes, boosting their visibility and calling upon collective brainpower and specialized expertise to work out complex problems, uncover clues in criminal cases, and explore or debunk conspiracies. The core concept isn't particularly novel; find one of its origins in the anonymous tip lines like **Crime Stoppers** that gained popularity in the '70s, or the "**Unsolved Mysteries** TV series, which premiered in 1987. But with the emergence of social networks and digitized media, public involvement has increased exponentially and become more complex and consequential. The phenomenon demonstrates (in theory) the long-standing principle of the "wisdom of the crowd," which postulates that the collective opinions and assertions of a group are more reliable, sensible, or morally sound than those of any its individuals—two heads are better than one, in other words. One of the most prominent cases of crowdsleuthing happened in the days following the attack on the U.S. Capitol, when tens of thousands of internet users mounted an in-depth investigation of digital assets—videos, texts, photos, geotags—posted by insurgents. Within two weeks, more than 70,000 tips had



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**Origin Wireless AI uses Wi-Fi sensing engines to detect activities of daily living, monitor sleep, notice falls, and send alerts to caregivers.**

been called in to the **Federal Bureau of Investigation** and police. But while these crowds of "digilantes" can serve as a valuable resource when uninterested, understaffed, or inept law enforcement agencies come up short—they've even successfully assisted in solving some murder cases—they sometimes cause more harm than good. Whether it's amateurs posing as experts or ideologue conspiracy theorists or bad actors looking to spread misinformation for personal gain or to undermine others, they all illustrate the perils inherent in crowdsourced crime-solving.

## Remote Worker Monitoring

Employees are data subjects too. As millions worked from home during the pandemic, companies launched mandatory monitoring systems and installed tracking software on work-issued computers to track productivity and, of course, monitor security. Programs ask employees to self-report time spent on tasks, while other systems take random screenshots throughout the day. More invasive programs log keystrokes. **Zoom**, among other video conference systems, offers attention tracking metrics, which shows administrators if anyone navigated away to a different application or webpage for longer than 30 seconds. Companies must consider the privacy of their employees as they work from home, and should be transparent about what systems are being used.

## Data Retention Policies

A data retention policy is a formalized protocol for retaining information, and historically companies have enacted them for compliance. Now that companies regularly use consumer and other sources of data, they are starting to build policies that are more protective. Regulatory frameworks such as the **General Data Protection Regulation** (GDPR) and the **California Consumer Privacy Act** (CCPA) are forcing companies to update their policies. But most companies are still very far behind, especially those not under the level of regulatory scrutiny applied to industries like finance and health care.

## Compliance Challenges and Unrealistic Budgets

The historical tension between security and privacy will unleash new challenges in the near future. Consumers shed more data each day, and as more connected devices enter the marketplace, the volume of available data will balloon. Yet those organizations creating devices and managing consumer data aren't planning for future scenarios. Managers will need to develop and continually update their security policies—and they'll need to make the details transparent. Most organizations aren't devoting enough dollars to securing their data and devices. Organizations that haven't carved out enough budget to secure their Internet of Things (IoT) environment will find themselves dealing with vast recalls, remediation, and lawsuits. A fragmented regulatory landscape promises a significant headache for compliance officers and risk managers, who must ensure that the policies and procedures for governments, companies, nonprofits, and news organizations are current.

## Drone Surveillance

Drones come in all shapes and sizes, and they can be used in a variety of settings for surveillance. Advanced camera technology can capture photos and video from 1,000 feet away, while machine learning software can remotely identify who we are and lock on to our bodies as we move around—all without our knowledge. They can also intercept mobile phone calls, gather license plate information, and determine whether someone is carrying a weapon. Powered by artificial intelligence (AI), **Skydio X2** is built for first responders and enterprise use—it has thermal sensors and night flight capabilities, allowing it to collect data for asset inspection, security patrol, and situational awareness. Early in the pandemic,


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Chinese municipalities were using drones to spy on neighborhood blocks; if citizens broke curfew and stayed outside too long, drones would fly low to physically intimidate them, forcing them back into their homes. (*See: Drones.*)

## Non-Line-of-Sight Tracking

The Wi-Fi transmitter in your home or office is continually sending and receiving information, which it converts into radio waves. The signals aren't very strong, only filling up the space around you (and possibly spilling just outside to the street). It turns out that, with the right device, it's possible to detect us moving through the signals as they bounce off us and onto other objects. What this means in practice: Wi-Fi signals can be harnessed to recognize us and our movements through our walls. **Origin Wireless AI** uses Wi-Fi sensing in its home security products. Its **Breathing AI Engine** captures the slightest chest movements using standard Wi-Fi. Understanding breathing patterns is one of the key factors for sleep monitoring and respiratory rate variability.

## Contact Tracing

Governments must track the spread of COVID-19 and its mutations, and that has led to a new purpose for mobile surveillance applications. While traditional contact tracing involved interviewing patients using a tedious script and asking them to recall recent interactions, the mobile apps take advantage of a phone's GPS data and Bluetooth signals. Within seconds, a contract tracing app would not only detect who is within an infected person's proximity, it would also have historical locations and could send notifications. In China, **Alibaba** and **Tencent** worked with the government to develop a color-coded tracking system and mobile phone app, which required citizens to enter their national ID numbers, health data, travel history, and more; the app then displayed a green (safe), yellow (self-quarantine), or red (report to a supervised facility immediately). Other countries, such as Bahrain, Kuwait, and Norway, developed countrywide tracing apps that didn't do a good job of anonymizing data stored on central servers. India launched a compulsory nationwide app, but it too had data privacy risks. As the virus continues to affect millions worldwide, contact tracing will be a public health priority in 2021, notwithstanding privacy risks.

## Data Privacy Enforcement Returns

When laws like GDPR came into effect, the focus was on fines and enforcement. The fear of violating the law worked to make responsible businesses comply. However, conflicting local and national laws, along with Covid-related work from home practices, prompted companies to eschew compliance in recent months. We are nonetheless likely to see a return to strict enforcement and renewed calls for national-level privacy regulations this year due to changes in government administration and vaccines.

## Fragmented Approaches to Privacy and Data Ownership

Who, exactly, owns our data is a topic of great concern worldwide. The reason: Defining ownership would have huge ramifications on what can be done with our data, who could gain access to it, and how it could be monetized. In a legal sense, data ownership has typically referred to IP or copyright data. However, the rise of wearable smart devices and IoT have made people more aware of how their behavior, health statistics, and online activity are collected and monetized by large companies. You do not own the site analytics that these tech giants make available to you, and you don't own any messages sent on a company email server or in your Slack channel. In a world where every device is smart and connected, surveillance is constant and ownership is unclear. For the past year, privacy and data ownership remained key topics of conversation, with some policymakers and CEOs advocating for a new paradigm in which consumers would "own" their data. Others recommended a model in which consumer data would be treated as a public good. The regulatory environment will only grow more fragmented in the coming year.

**CCPA** came into effect in January 2020, to govern how businesses collect and share personal information in California, and **GDPR** is now being enforced. Illinois has a restrictive state law on the books preventing automatic face recognition and tagging, but if you cross the border into Indiana, there are much more lax restrictions on collecting and using an adult's data. With a new administration in the White House and a Democratic majority in Congress, we expect to see a baseline privacy law implemented in the U.S.



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New surveillance technologies are active around the world.

## Privacy and Unionizing at Big Tech

**Amazon** employees started an anti-surveillance petition in 2020 with a singular message: "Stop spying on us." The call to action stemmed from reports that Amazon-owned **Whole Foods** was tracking and scoring employees it deemed risky of unionizing. Scores were based on more than 24 metrics, including racial diversity, employee loyalty, and violations reported to the **Occupational Safety and Health Administration**. 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 allyship with the **Communications Workers of America**.

## Encrypted Messaging Networks

In the past year, journalists have relied on closed, encrypted messaging networks like **Keybase** and **Signal**. However, many news organizations do not have guidelines on how these networks can and should be used at work. For example, a company may determine that emails are its intellectual property and subject to professional codes of conduct; what about messages sent through encrypted networks? In reaction to revelations about social media hacks and government-sponsored surveillance programs worldwide, private networks will continue to be popular in 2021.

## Biological Privacy

Open source genealogy website GEDmatch allows users to voluntarily share their genetic profiles for free, as a way to find relatives and trace their genealogies. Law enforcement used GEDmatch to track down Joseph James DeAngelo, the suspected Golden State Killer who over a period of years raped 45 women and killed more than a dozen people. He never sent in a biological sample, but it turns out that someone connected to him did. In another case, a genetic test led to a Utah high school student's arrest



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after his saliva on a discarded milk carton matched a blood sample at a crime scene. If someone you know—or someone who might in some way be connected to you—submits their information to an open source website, it can be traced back to you. Meanwhile, new cameras are being deployed to detect Covid cases. Bosch security cameras include integrated intelligent video analysis, showing body temperature. Its open camera platform uses computer vision to determine the number of people in a space who are complying with coronavirus restrictions.

## Depth of Field Recognition

3D cameras that have good depth of field—which were originally intended for content creation—are being repurposed as surveillance systems. 3D cameras alongside LiDAR can generate rich images, wireframes, and more.

## Personal Electronic Keys

Companies such as Tesla and Audi now rely more on electronic keys for vehicle entry. Audi's 2022 all-electric E-tron asks each driver to create a user profile. When connected to the Audi app, the car can be remotely monitored—even when someone else is driving it. Similarly, the Lockly Duo smart lock allows users to create multiple profiles for friends and family, includes a shuffling keypad—picture a screen with digital buttons that rearrange after each use—and requires fingerprints for added security.

## Public Entities Selling Private Data

A number of public departments sell personal data in the U.S. In 2019, California's DMV (Department of Motor Vehicles) reportedly earned $51 million. As of this report's writing, local lawmakers had not determined whether consumer protections should be extended, nor the kinds of companies that bought the data. DMVs in Florida, Delaware, Indiana, New Jersey, Rhode Island, and Wisconsin package and sell driver data. Technically this is legal, under the 1994 Driver's Privacy Protection Act, which was initially meant to limit public access to personal data after the gruesome murder of a woman whose stalker found her using DMV records. But with many exceptions to the act, just about anyone can lawfully gain access in certain states.

## GDPR Copycats

The year 2021 marks the third anniversary of GDPR. When it went into effect, companies were understandably anxious about compliance. Microsoft dedicated more than 1,600 engineers to work on GDPR compliance projects, while Google Chief Privacy Officer Keith Enright estimated that Google had spent "hundreds of years of human time" to comply with the European Union rules. In January 2020, CCPA went into effect, and other countries are now developing their own versions of GDPR. We anticipate the U.S. launching an effort to standardize privacy regulation under the Biden administration.

## Eavesdropping Rights

Should consumers be given the right to eavesdrop on what their own devices are saying, and who else is listening in? As we connect more IoT devices—fitness trackers, mobile phones, cars, coffee makers—tthey're learning about us, starting to talk to one another about us, and reporting everything to the companies that make them. News and entertainment companies must determine whether those devices, working as intermediaries, are crossing any ethical lines when consumer data is exchanging hands. As the Biden administration strengthens the federal agencies charged with monitoring consumer protections, we anticipate changes to existing rules in 2021 (at least in the U.S.).

## Preventing Digital Self-Incrimination

Whether they're using a connected fitness device, a smart earphone, or a pair of smart glasses, consumers will find themselves continuously monitoring—and being monitored—by third parties. Our legal system isn't keeping pace with technology, so we lack norms, standards, and case law on how data collected from and produced by our wearables can be used. To date, fitness devices, pacemakers, and smartwatches have been used as evidence. In the U.S., judges get to decide whether to allow data from wearable devices, or whether individuals still have a reasonable expectation of privacy if they've been actively sharing their fitness stats in the cloud or with third parties. But we're about to see a flurry of new cases. Hundreds of people who stormed the U.S. Capitol posted content, emitted geodata, and made phone calls, all of which could be used as evidence in criminal proceedings.


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# Privacy Trends

## Differential Privacy

Differential privacy as a mathematical concept has been around since 2006, when Cynthia Dwork, Frank McSherry, Kobbi Nissim, and Adam Smith first developed this new approach, also known as "epsilon indistinguishability." Dwork once explained that differential privacy is achieved when "the outcome of any analysis is essentially equally likely, independent of whether any individual joins, or refrains from joining, the dataset." Differential privacy is achieved by strategically introducing random noise into the dataset. It is most useful when answering simple (low-sensitivity) queries. It's good for finding out traffic patterns in Google Maps, the most popular emoji for iPhone users, and ride-sharing trends across Uber's global network while keeping individual user behavior anonymous. 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. But it is important to remember this method is still evolving. Depending on applications and datasets, differential privacy is harder to maintain when variables are correlated. Plus, at the moment, there is scant regulatory guidance.

## Defining Online Harassment

The #MeToo movement brought to light thousands of stories of sexual harassment and resulted in the ousting of more than a dozen high-profile men throughout 2018 and 2019. A shared Google document, dubbed the "Shitty Media Men" list, was at one point circulating among female journalists, who entered the details of men who had sexually harassed women in the real world. When the list was leaked, some pointed the finger at the women, arguing that they were committing acts of online harassment simply by contributing to it. Far-right extremists have complained about being targeted online and shamed for their beliefs in debunked conspiracy theories, such as QAnon, and they were validated by former President Donald Trump. We don't yet have clear definitions for what constitutes harassment. In the years ahead, we will continue to wrestle with what behavior is acceptable in virtual gaming worlds, social media, our mobile exchanges, and general digital discourse.

## Safeguarding and Verifying Leaked Data

Many social movements worldwide encourage the leaking of sensitive information to the press, to hackers, and to other governments. While many people seem eager to find and share information, not everyone agrees on what should be published, and by whom. In January 2020, a massive leak involving more than 700,000 documents implicated one of Africa's wealthiest people in a massive scheme of fraud and money laundering. The International Consortium of Investigative Journalists (ICIJ)—a collaboration between 370 journalists from 76 countries—took on a sweeping investigation of Isabel dos Santos, the billionaire and former first daughter of Angola. Angola's top prosecutor has since accused her of embezzlement, influence peddling, harmful management, forgery of documents, and other so-called economic crimes. Previously, the ICIJ spent a year reporting on a massive cache of 11.5 million leaked records showing the offshore holdings of 140 politicians from around the world, including 12 current and former world leaders, and more. The records, known as the Panama Papers, were sent from a little-known law firm in Panama. In 2017, the U.S. Senate Committee on Homeland Security and Governmental Affairs issued a report titled "State Secrets: How an Avalanche of Media Leaks Is Harming National Security" and cited 125 stories with leaked information that the committee considered damaging to national security. Media organizations like The New York Times and The Guardian created secure sections on their websites where people can safely upload sensitive documents to journalists, and now, political action groups and activists are seeking confidential document leaks too. Most recently, in the aftermath of the U.S. Capitol insurgence, hackers infiltrated the alt-right social network Parler and released a trove of user data. You can expect to see more coordinated efforts to seek and produce leaked data in 2021 and beyond.


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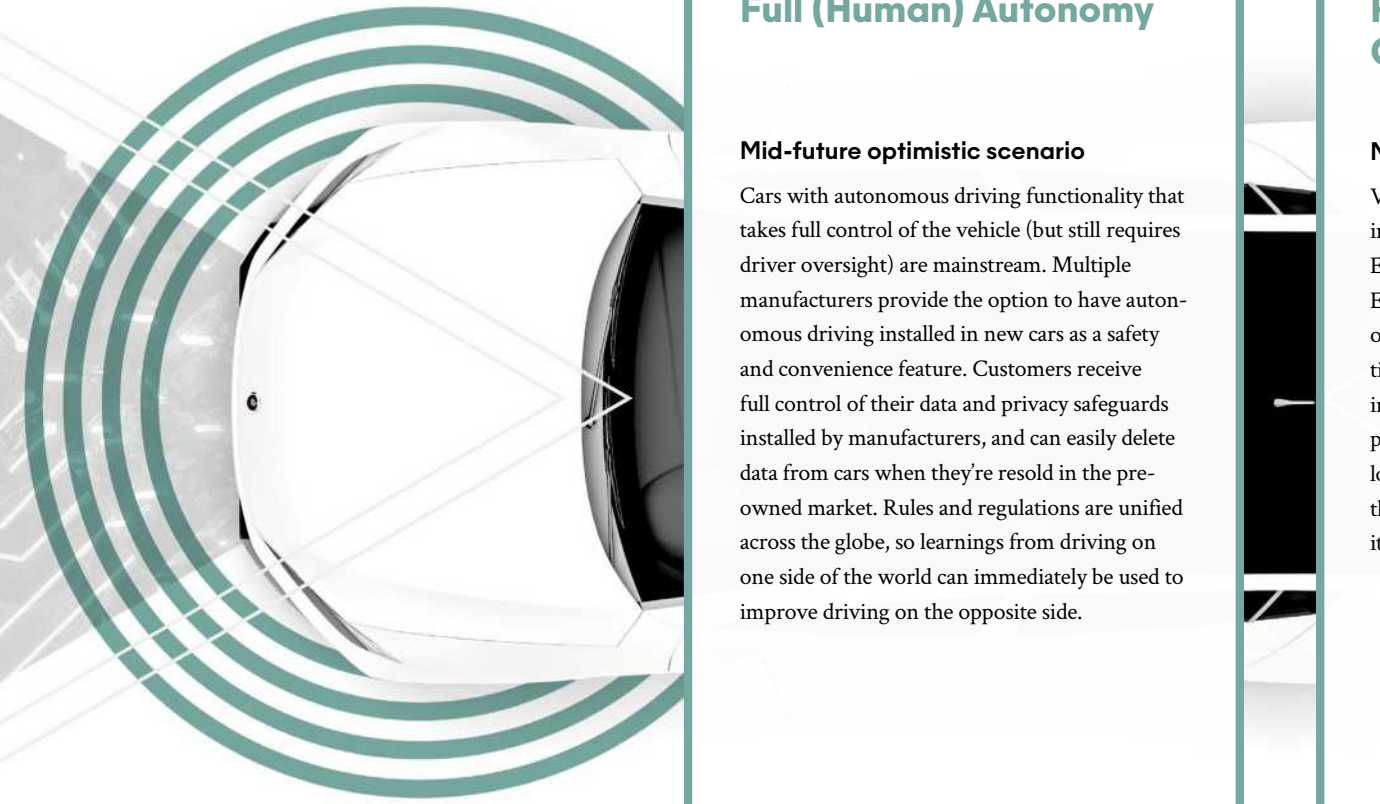

## Full (Human) Autonomy

### Mid-future optimistic scenario

Cars with autonomous driving functionality that takes full control of the vehicle (but still requires driver oversight) are mainstream. Multiple manufacturers provide the option to have autonomous driving installed in new cars as a safety and convenience feature. Customers receive full control of their data and privacy safeguards installed by manufacturers, and can easily delete data from cars when they're resold in the pre-owned market. Rules and regulations are unified across the globe, so learnings from driving on one side of the world can immediately be used to improve driving on the opposite side.

## Regional Privacy Challenges

### Mid-future neutral scenario

Vehicles have regional requirements but are interoperable at the continental level. Cars in Europe can function throughout most of the European Union and vehicles in America can operate across most states. Standardized production looks very similar to the manufacturing and internet privacy rules of the early 2020s, where products can be made globally and customized locally. The implementation of privacy protocols therefore falls to each region, and is voted on by its constituents.

## Uncrossable Borders

### Mid-future catastrophic scenario

Fragmentation of regulation and data privacy causes a complete lack of interoperability. You can't take a car designed for one state to the next due to regulations that limit design, features, and functionality. Car manufacturers are forced to design platforms and brands for specific jurisdictions. This prevents the ability to have standardized worldwide platforms in manufacturing, driving up production costs, dramatically decreasing the speed of improvements, and extending development cycles exponentially. You have to stop at every border and create a new account for your car with additional information and accept the terms and conditions of operating the vehicle in the next jurisdiction. Certain features and functions are enabled or disabled based on where you are traveling and what terms and conditions you accept, and your insurance may only cover you in some areas and circumstances.

# Scenarios



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# China's Panopticon

A Global Tone Communication Technology director stands at a podium in front of a screen reading: "90% of military-level intelligence can be obtained ... through open-source data."

Photo courtesy of Dr. Samantha Hoffman.

China collects massive amounts of data—on its own citizens and on others (people, businesses, governments) around the world. The Chinese Communist Party (CCP) places a priority on data for intelligence, propaganda, and surveillance.

The CCP collects data through typical channels, such as security cameras in public spaces and social networks. But its reach is staggering: The government scrapes data from smart city infrastructure, school records systems, e-commerce apps, payment systems, and more. The country's massive population—nearing 1.4 billion people—offers researchers and startups access to a wellspring of 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. Bulk data collection is used to train recognition algorithms, which is why China has some of the world's leading voice, face, and gesture recognition systems. Chinese startup SenseTime is pioneering myriad recognition technologies, including a system that provides advertisers real-time feedback on what people are watching, technologies 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, whether it's people, pets, automobiles, trees, or soda cans.

A little-known company called Global Tone Communication Technology, which is controlled by the CCP, reportedly collects 10 terabytes of data every day from various online sources. That's the equivalent of about 20 billion Instagram photos. The company has boasted about being able to mine data in 65 languages simultaneously at a rate of 16,000 words per second.

One of its data sources is an app beloved by people around the world: TikTok. This is partly what has governments concerned about the growing popularity of the social video sharing app. ByteDance, TikTok's parent company, has maintained that it is an independent company and announced changes in September it hoped would satisfy the U.S. government. These included giving Oracle and Walmart ownership stakes in the company, but several botched attempts by the former Trump administration to ban the app were thwarted in federal court.

This isn't about nudging consumers to buy more products. Security experts warn that TikTok, as well as other Chinese apps like messaging service WeChat and payment system AliPay, are dangerous conduits for CCP surveillance and disinformation campaigns. The CCP is interested in exerting authoritarian control over its citizens and those wishing to do business in China. The CCP is cleverly using capitalism as a gateway to amass rich user profiles, thwart challenges to free speech, and maintain control.



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## Privacy Protection Startups

**Near-future neutral scenario**

When personal information is weaponized, efforts to protect it prove profitable. A new crop of vigilante startups help you protect yourself—for a price. These startups offer new products and services that obscure your identity, create false data to misdirect platforms, and generate white noise to prevent your devices from eavesdropping. They even create digital safe boxes around your online profiles to prevent platforms and people from selling you out. The combined effect of real risk and rampant paranoia among users ensures that privacy stays a lucrative business.

# Security

10TH YEAR ON THE LIST

# Security

SolarWinds marked one of the worst supply chain attacks in history.

KEY INSIGHT

**From a security standpoint, 2020 was the worst year on record. From compromised high-profile social media accounts to the most significant cyberattack in modern history, chief information security officers found themselves addressing existing problems while trying to anticipate security challenges on the horizon.**

EXAMPLES

COVID-19 played a role in new forms of cyberattacks. Companies switched to remote work overnight, yet hospitals, schools, city halls, and businesses had security gaps that hackers exploited. IT teams rushed to ensure files, software, and databases were accessible for remote work, but as many as 93% of IT teams delayed security projects, and 43% have since delayed or stopped patching altogether, according to a survey by security management provider Tanium. And 85% of IT teams have seen more cyberattacks since the pandemic's start, and thieves stole confidential information, passwords, addresses, and other records. In other cases, hospital records systems, city websites, and school email servers were penetrated and held for ransom.

Last year, attackers breached what's known as the security supply chain by infiltrating SolarWinds, an IT contractor used by 330,000 companies and organizations. The National Security Agency and FBI say that Russia was likely behind the attack and likely had access to critical data for months before being detected. Nearly all Fortune 500 companies use SolarWinds products to monitor their networks, but so do government agencies (U.S. Department of Homeland Security, parts of the Pentagon), defense contractors (Boeing), and important research agencies (Los Alamos National Laboratory, where our nuclear weapons are designed). The attack was sophisticated and difficult to undo, and it compromised critical infrastructure.

Hackers penetrated a server used to build updates for the SolarWinds Orion Platform, and used that server to insert backdoor malware into products used by Microsoft and FireEye. Microsoft quickly and decisively mitigated the damage by mobilizing to remove digital certificates, removing the domains used by the malware for command and control, updating the anti-malware capabilities built into Windows, and automatically quarantining systems with malware detected.



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# Security continued

Clear Health Pass uses biometric data to monitor people in public places.

## DISRUPTIVE IMPACT

A company's information assets, data, and technology are its critical infrastructure, yet cybersecurity is a continuously moving target. The price tag to secure a company's data and IT infrastructure is minimal compared to the cost of breach. The average total cost of a data breach is $3.86 million, according to IBM's annual Cost of a Data Breach Report, and it can take months to identify and contain an attack. Securing IT resources from malicious actors is paramount in the years ahead.

## EMERGING PLAYERS

- Russian Foreign Intelligence Service
- U.S. Cybersecurity and Infrastructure Agency
- WireGuard VPN
- Palantir Technologies
- Darktrace
- Nuance Communications
- Sonatype
- Deep Instinct
- Qualys
- Fortinet
- Securiti.AI



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# Security continued

## A very brief list of 2020 attacks and breaches.

### January

- **Cyberattack:** A Chinese group targeted Mitsubishi in a massive cyberattack that compromised the personal data of 8,000 individuals, as well as information relating to partnering businesses and government agencies—including defense equipment projects.
- **Ransomware:** The Tampa Bay Times was hit with "Ryuk," a ransomware strain used to target large businesses and agencies.
- **Ransomware attack:** Tillamook County in Oregon had its computer and telephone systems taken offline.
- **Cyberattack:** An Iranian-sponsored threat actor hacked a U.S. federal government library depository website to display messages vowing to avenge the killing of Qasem Soleimani, a military general. It also displayed an image of former President Trump being punched in the face.

### February

- **Ransomware attack:** Toll Group, an Australia-based logistics company, was attacked twice in three months.
- **Cyberattack:** Chinese hackers targeted Malaysian government officials to steal data related to government-backed projects in the region.
- **Data breach:** Hackers exposed 440 million internal records at Estée Lauder due to middleware security failures.
- **Data breach:** The Defense Information Systems Agency, which handles IT for the White House, admitted a data breach potentially compromised employee records.
- **Data breach:** Clearview AI's controversial client list was stolen due to a software vulnerability.

### March

- **Cyber espionage:** Chinese hackers targeted more than 75 organizations around the world in the manufacturing, media, health care, and nonprofit sectors as part of a broad-ranging cyber espionage campaign.
- **Data breach:** Hackers breached the anonymous social media app Whisper, which lets people share secrets, exposing millions of users' private profiles and datasets.
- **Data breach:** More than 5 million Marriott guests had their information taken when a hacker gained access to guest records using the login credentials of two employees at franchise properties.

### April

- **Cyberattack:** U.S. officials reported seeing a surge of attacks by Chinese hackers against health care providers, pharmaceutical manufacturers, and the U.S. Department of Health and Human Services amid the COVID-19 pandemic.

### May

- **Ransomware:** Hackers breached health care insurance giant Magellan Health and exfiltrated the logins, personal information, and tax information of 365,000 patients.
- **Cyberattack:** Japan's Defense Ministry announced it was investigating a large-scale cyber attack against Mitsubishi Electric that could have compromised details of new state-of-the-art missile designs.
- **Data breach:** Chinese hackers accessed the travel records of 9 million customers of U.K. airline group EasyJet.

### June

- **Data breach:** The Nova Scotia Health Authority discovered that 3,000 patients had their personal health information stolen.
- **DDoS attack:** Amazon Web Services mitigated a massive 2.3 Tbps DDoS attack.

### July

- **Data breach:** A 17-year-old breached Twitter, hacking dozens of high-profile accounts, including former President Barack Obama, Amazon CEO Jeff Bezos, and Tesla and SpaceX CEO Elon Musk.
- **Cyberattack:** Navigation systems provider Garmin was attacked; its devices and systems were forced offline.



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# Security continued

## A very brief list of 2020 attacks and breaches.

### August

- **Ransomware:** An online gang known as "Maze" hit Canon with a ransomware attack.
- **Leak:** 20 gigabytes of sensitive Intel corporate data was leaked online.

### September

- **Cyber homicide:** In Germany, a patient died after being redirected away from a hospital that was in the middle of an active ransomware infiltration.

### October

- **Direct-to-consumer ransomware attack:** Vastaamo, a psychotherapy center in Finland, had confidential patient records stolen. In a unique twist, hackers went straight to the patients and blackmailed them directly.
- **DDoS attack:** Google mitigated a 2.54 Tbps DDoS attack, one of the largest ever recorded.

### November

- **Data breach:** Hackers exposed the personal data of 16 million Brazilian Covid patients online after breaching two Brazillian government databases. Among those affected by the leak were Brazil President Jair Bolsonaro, seven ministers, and 17 provincial governors.
- **Data breach:** Hackers breached the Christian faith app Pray.com, leaking private data of 10 million users. Financial information was one of the key gets in this attack: Donations processed by the app show how and when users contributed.
- **Vulnerability:** A website created by consultancy Deloitte titled "Test Your Hacker IQ" inadvertently exposed the database username and password in its configuration files. The site was hosted on an older version of Ubuntu, aLinux system that no longer received security patches. Deloitte later said that it was a legacy site created for an event; however, it was never removed. (This is a good reminder that legacy content can cause future security headaches for companies.)
- **Data breach:** Folksam, one of Sweden's largest insurance companies, shared the personal information—including pregnancies and other intimate details—of 1 million Swedes with third parties.

### December

- **Cyberattack:** FireEye disclosed an attack resulting in penetration tools (code that can be used to breach computer systems, or test for and detect breaches) being stolen.
- **Ransomware:** Hackers crippled the digital systems of the city of New Orleans.
- **Bio-Cyberattack:** Hackers accessed data related to the Covid vaccine being developed by Pfizer during an attack on the European Medicines Agency.


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# Security Trends

**When ESPN cut to the draft headquarters of Bill Belichick, head coach of the New England Patriots, during the second round of the virtual 2020 NFL draft, his dog—an Alaskan Klee Kai named Nike—was seated all alone by two laptops.**

Photo courtesy of Twitter.com/katfominykh.

## Bio-Cyberattacks

With the global COVID-19 pandemic forcing fast coordination by government agencies, researchers, and pharmaceutical companies, vaccine data became a new target for cyberattacks. Hackers are working to gain access related to Covid research, genetic code, and vaccines. In December 2020, hackers penetrated the European Medicines Agency, stealing data related to the vaccine developed by Pfizer.

## Biometric Malware

Kaspersky researchers found that in the third quarter of 2019 alone, about 33% of the systems that use and store biometric data were targets of malware attacks. Biometric data isn't stored as securely as it should be, opening the door to theft and manipulation. We saw that in the U.S. in 2019, when a massive data breach compromised 100,000 facial images and 105,000 license plate images collected by the U.S. Customs and Border Protection. Several of those images were posted to the dark web. There have been plenty of attacks in recent years, including the emergence of a tool in 2018 that scraped photos from social media and used 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, which resulted 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, which resulted in her being transferred to another hospital. Time ran out, and she died. 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.

## Supply Chain Attacks

Cybersecurity has its own supply chain, which includes IT services, vendors, software, networks, and data. The SolarWinds attack last year is an example of a supply chain attack, because it compromised the systems management tools used by IT professionals. It 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.


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# Security Trends

Remote employee tracking software was widely deployed in 2020.

## Techlash Leads to Messy Code and Security Problems

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 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. Facebook-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 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.

## 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. From February through April 2020, hackers used zero-days to target Microsoft and Google, making use of two exploit servers: one for Windows and the other for Android. They used well-engineered complex code with novel exploit systems, revealing new exploit chains. (Both companies have since patched security flaws.) 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.



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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 cryptocurrency startup Ethereum is using zero-knowledge for authentication. Sedicii and SecureAuth make and sell zero-proof software.

## 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 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, NSA 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. Tech leaders warn that the proposed act, introduced by then Senate Judiciary Chairman Lindsey Graham and U.S. Sens. Tom Cotton (R-Ark.) and Marsha Blackburn (R-Tenn.), would undermine privacy and security protections built into the technologies we use. 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.

## 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.

## Consumer IoT Vulnerabilities

With the proliferation of smart devices—connected speakers, mirrors, and fitness gadgets—and millions of people working from home, hackers have a wellspring of new targets in 2021. Especially because consumers don't always update firmware, security patches, or even their passwords. IoT 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



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Biometric security features are coming to many devices in 2021.

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.

## Data Theft Becomes Data Manipulation

Rather than malicious actors simply stealing data, you can expect to see new kinds of attacks in 2021 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.

## 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.

## AI-Powered Automated Hacking Systems

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. This could pose a significant threat to news, eSports, and entertainment companies.

## 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 anticipate new cases of internet traffic hijacking in 2021, especially as people continue to socially distance indoors and stream content.

## 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 have spiked—and they are increasing in both reach and duration. DDoS attacks were up 25% last year alone, and public institutions were warned of more than 50 credible threats. To date, half of the world's attacks have originated in China. Hackers are using more sophisticated tools, which means that future



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attacks will be larger in scope and could achieve greater impact.

### Third-Party Verified Identities

U.S. citizens must continually hand over their social security numbers for authentication. But in the wake of the massive Equifax data breach, it has become clear that our social security numbers—a single identifier used in everything from bank accounts, to health insurance, even with the university registrar—aren't secure. These numbers were never intended to be used as general-purpose passwords. We will start to see the emergence of third-party, nongovernmental providers of verified identities. One example that's already in the marketplace is Clear, the trusted traveler program that lets verified customers get through airport security faster. Last year, it announced plans for comprehensive verification for digital identity, as well as health and vaccination records.

### Ransomware-as-a-Service

Last year, ransomware devastated companies and even entire cities. Entertainment and news media organizations could be next. 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 2019, New Orleans 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 Hacktivists

Hackers-turned-activists have had a busy few years, working for causes they believe in. They launched DDoS attacks against governments, corporations, and banks. Hacktivist 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. Given ongoing heated political tensions, we'll likely see more operations being carried out this year. Hacktivists will use their skills to help shape local, state, national, and international politics, conversations, and business practices. (*See: Crowdsleuthing.*)

### Weird Glitches

Glitches are problems that don't have an immediate, obvious cause but nonetheless can create frustrating problems. Glitches are so common now they don't always make the news—but there were hundreds in the spring and fall of 2020, as students went to virtual school. Online learning platform Blackboard reported that students couldn't register on the first day of school and pages loaded slowly. Technical and user errors riddled last year's NFL draft, held virtually amid the pandemic. When cameras cut to Bill Belichick's home after the New England Patriots selected safety Kyle Dugger, the coach had left his table—but his dog was waiting patiently at a computer and staring into the camera. From customs and border protection terminals going dark to technical malfunctions on assembly lines, glitches affect every industry. They often result from newer technologies, which break in unexpected ways. And often, glitches stem from not thinking technology through, from imagined use cases to actual real-world usage.

### Open Source App Vulnerabilities

The SolarWinds breach gave new attention to unintentional vulnerabilities in code, especially with a booming market for malware that exploits vulnerabilities in open-source applications and software. As the AI ecosystem grows to incorporate more open source code and community-built tools, it will be especially important to spot problems in advance. WhiteSource's Vulnerability Database continuously updates its library with emerging threats and available fixes.

### 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



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Clear announced plans for comprehensive verification for digital identity.

in cyberspace. Noticeably absent from the list of signers: Russia, China, North Korea, Israel, and the United States. But that could change in 2021. The Biden administration signaled its focus on cybersecurity as a top national security policy in January, as it staffed departments with appointees. Cybersecurity will be a key foreign policy issue, a critical national security issue, and a formal component of the new administration's leadership.

## 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.

## 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 being used by the U.S. Department of Defense, WordPress, Coinbase, Shopify, and GitHub. In 2021, 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. Google has paid out more than $21 million since it launched its bug bounty program in November 2010.

## Magnetic Tape Supply Shortages

It's odd to think that in 2021 the world still relies on magnetic tape—those clunky old cartridges used decades ago to store data. And yet that's still the preferred method of backups for many companies needing to safeguard their most precious information. Our critical financial data and scientific records may be kept on cloud servers at Microsoft, Amazon, and Google, but duplicate copies are backed up to tape. The problem is that consolidation has left us with just two companies—Sony and Fujifilm Holdings—that still manufacture tape. For four years, Fujifilm and Sony remained locked in a feud over alleged patent infringement, which resulted in Sony being banned from importing media tape. The case was settled in the fall, but it caused widespread shortages. Tape isn't a big business unit within these otherwise sprawling companies, and this could lead to problems down the road for the world's data archives, especially because the creation of critical data increases significantly each year.

## State-sponsored Security Breaches

It's thought that the SolarWinds supply chain attack was likely planned and facilitated by an elite Russian government


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# Security Trends

There is a global magnetic tape storage.

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. This past February, it was revealed that hackers had remotely accessed the water supply of a city near Tampa Bay, Florida, and had adjusted the amount 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 three 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. Cybersecurity company Symantec has warned that hackers have already 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 NSA—are playing offense, especially as artificial intelligence becomes a focus for the nation's cyber strategy. Eventually, artificial intelligence 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.



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It's critical that we step back and assess the significance of these attacks in their full context. This is not 'espionage as usual,' even in the digital age. Instead, it represents an act of recklessness that created a serious technological vulnerability for the United States and the world. In effect, this is not just an attack on specific targets, but on the trust and reliability of the world's critical infrastructure in order to advance one nation's intelligence agency. While the most recent attack appears to reflect a particular focus on the United States and many other democracies, it also provides a powerful reminder that people in virtually every country are at risk and need protection irrespective of the governments they live under.

— Brad Smith, president, Microsoft (in response to the FireEye hack)

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## Misinformation Moats

**Mid-future optimistic scenario**

Pervasive hacking and threats of cyberwarfare inspire a new wave of cybersecurity solutions. Borrowing from tactics used in national elections, cybersecurity companies design strategic layers of misinformation to protect their clients' intellectual property. These moats lie just inside firewalls and act as a second barrier against hackers. Misinformation moats are filled with bad data, misleading information, and even malicious software. When hackers access the moat, they think they've found what they're looking for, leaving the true payload protected.



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# 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 take-down 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.

### 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.



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# Cybersecurity Terms Every Executive Should Know

### 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 an reductive, distinctly negative connotation.

### Hacktivist
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, InoSec 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.

### 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.



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# Cybersecurity Terms Every Executive Should Know

### 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 Tool. 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.

### 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.



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# Application

## STRATEGY

Privacy and security are not issues specific to the CIO, CTO, CISO, or IT departments. How companies collect, use, and store data; the technology acquisitions business units make; the vendors and partners selected; and investments made in security all affect the future of a company. Responsibilities should be shared across the organization, as the evolving nature of security and privacy directly impact corporate strategic initiatives in a variety of areas, like digital transformation, growing operating income, international expansion, and more. Nearly every aspect of a chief strategy officer's work intersects with privacy and security.

## INNOVATION

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

Privacy and 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.

## RISK

Cyber espionage is a growing threat, and successful companies are clear targets: Criminals want to steal valuable IP from the world's best businesses. Chief risk management officers and those who work in risk-related positions can play a critical role in protecting a company's most important assets by championing data auditing, promoting proper data governance and management, and advocating for a risk-driven approach in departments that rely on data.



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# 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 about security and privacy:

1

Is our company's board of directors briefed regularly by our CISO?

Is our board fully engaged in issues related to privacy and cybersecurity?

2

What parts of our business make us a target for attacks?

When was the last time we audited the systems that keep those parts of our business safe?

3

Will our current approach to data collection, storage, encryption (and, if applicable, reselling) cause future problems?

What assumptions must hold true for our current strategy to succeed?

How will we make needed changes?



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Volume 9 of 12

14th Annual Edition

# 2021 Tech Trends Report

Strategic trends that will influence business, government, education, media and society in the coming year.

- Blockchain
- Fintech
- Crypto

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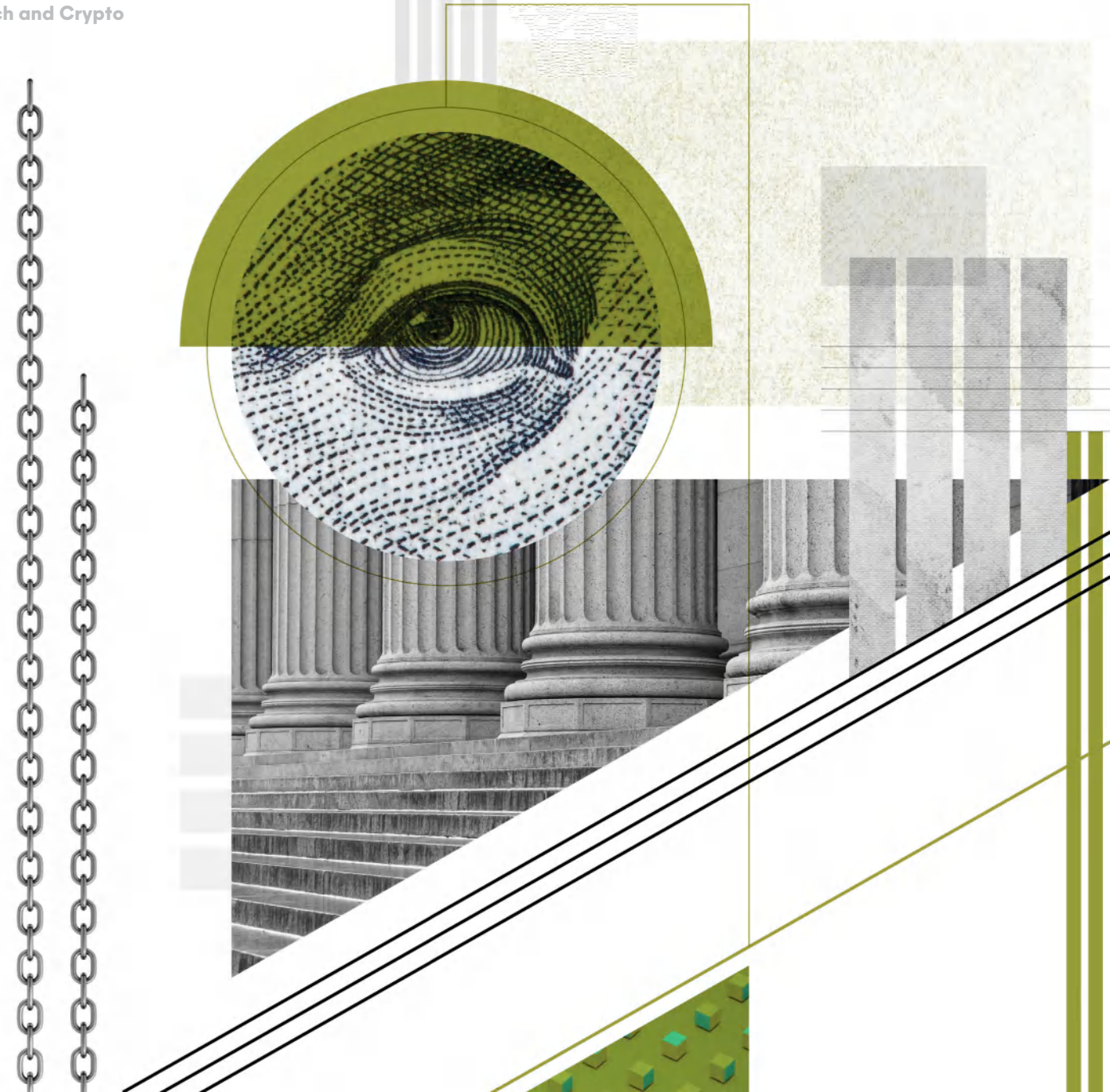

# Blockchain Fintech & Crypto Summary

- Large crypto-currency holdings will catalyze innovation in 2021, as bitcoin is used to collateralize new or experimental decentralized financial instruments.
- Decentralized financial technologies will be adopted by the enterprise.
- Four dozen countries are piloting digital fiat sovereign currencies.
- Environmental, social, governance (ESG) goals are driving blockchain adoption, as investors seek proof of improvements in supply chains.
- Demand for modern, impartial, and secure systems to settle trades and transactions will increase as the global financial system digitizes.
- Smart contracts will remove intermediaries, such as management and distribution companies, in creative fields.
- New platforms monetize idle computer resources. To earn extra money, consumers will grant access to their mobile phones, tablets, and connected home appliances when they're not used.
- Investors are using fractional ownership to divide the costs and risks of assets. It's a time-share model, based on blockchain, for fine art and collectibles.
- It's CryptoKitties, part two. As demand for non-fungible tokens spikes, digital collectibles will gain interoperability this year.



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**Rob Paone**
@crypto_bobby

You did the right thing.

Memorized The Intelligent Investor at age 15. Undergrad at Harvard. First job at GS. Got your CFA. MBA from Wharton. Opened your own fund after finely tuning your craft.

And then you were liquidated by a coalition of chicken tender eating HS dropouts.

4:38 PM · Jan 26, 2021 · Twitter Web App

**698** Retweets **1,174** Quote Tweets **5,166** Likes

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2ND YEAR ON THE LIST

# Central Bank-Backed Digital Currencies

China is a leader in the field of central bank digital currencies.

## KEY INSIGHT

**Central banks are issuing and regulating blockchain-backed tokens called digital state currencies—or central bank digital currencies or CBDCs—which could modernize some of the most antiquated areas of global finance. Despite the popularity of digital payment rails (the infrastructure that allows payment transfers from one party to another), the global monetary system is still largely based on state-backed, physical fiat currencies.**

## EXAMPLES

In 2018, the Marshall Islands created a new digital currency called the Sovereign (SOV), which is now legal tender in the Micronesian nation. Singapore's central bank created a digital currency backed by the Singapore dollar that runs on the Ethereum blockchain. Canada's central bank has been researching the issuing of a digital currency. China is the undisputed leader in CBDCs, successfully executing a large-scale pilot of more than 4 million digital yuan transactions from April to December 2020. An international coalition of central banks, including the Bank of Canada, Bank of England, Bank of Japan, European Central Bank, and U.S. Federal Reserve, issued a report in October 2020 outlining key principles for CBDCs.

## DISRUPTIVE IMPACT

More central banks may soon embrace CBDCs, paving the way for more streamlined flows of global currencies and foreign exchange markets. In fact, as many as 70% of central banks are actively exploring this technology to develop their own decentralized currencies, according to professional services firm PwC. When it comes to natural disasters, pandemics, and humanitarian aid, CBDCs could deliver emergency relief funds faster and enable easier tracking and monitoring of digital currencies. Yet for that reason, critics say that CBDCs also present privacy and surveillance concerns. The popularity of CBDCs prompted the World Economic Forum to publish a policymaker toolkit to ensure the improvement of payment systems' safety, resilience, and efficiency; increased financial inclusion; and better data transmission and reporting to central banks.

## EMERGING PLAYERS

- Bank of China
- Bank of International Settlements
- Worldwide central banks
- World Economic Forum



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1ST YEAR ON THE LIST

# Stablecoins

Tether's value proposition is that it is "tethered" to the value of a dollar.

## KEY INSIGHT

**Stablecoins work to minimize the volatility of the price of a crypto-currency, by "pegging" them to a specific exchange rate for a currency, crypto-currency, fiat money, or an exchange-traded commodity.**

## EXAMPLES

Visa and peer-to-peer payment company Circle Internet Financial created a credit card that uses USDC, a stablecoin pegged to the dollar. The underlying peg of another stablecoin, Facebook's Diem (formerly Libra), has yet to be announced. The New York attorney general's office and the U.S. Justice Department investigated whether Tether, the most widely used stablecoin, was used in cover-ups and market manipulations. (Tether admitted to no wrongdoing and settled for $18.5 million in February.) 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. The controversy has not hampered investor interest or global adoption. The stablecoin regulatory landscape is evolving. In late 2020, U.S. Rep. Rashida Tlaib (D-Mich.) introduced the STABLE Act to require companies issuing stablecoins obtain a banking license.

## DISRUPTIVE IMPACT

Stablecoins—specifically those pegged to the U.S. dollar—open up a universal means of exchange across the globe without traditional financial hurdles. People can now store savings in a stable asset rather than a local currency suffering from inflation, and stablecoins offer faster, more affordable remittances. This also raises regulatory concerns for circumstances in which stablecoins are used to evade currency controls and sanctions.

## EMERGING PLAYERS

- Tether
- Circle
- Coinbase
- Gemini
- Binance



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12TH YEAR ON THE LIST

# Social Payments

These apps blur the lines between sending money to a friend versus to a store.

## KEY INSIGHT

**Tech companies are leveraging APIs and digital infrastructure to provide seamless, interconnected financial services. Financial institutions and payment providers are integrating with tech platforms and e-commerce to acquire more customers and fend off competition.**

## EXAMPLES

In 2009, Venmo became the first social payment app, requiring users to caption their transactions and offering the option to share transactions publicly. Owned by PayPal, it now has 300 million users, and social payments is a serious financial service sector. China's Alipay gives its 870 million users access to wealth management services, loan applications, and credit scores—and issued half a billion dollars in Chinese loans in 2020. Facebook's new WhatsApp Pay has 400 million users in India. Apple and Goldman Sachs created a credit card for iPhones and Apple Watches. Uber Money will build a bank for its drivers. Amazon is exploring a checking account service to go with its existing branded credit card. This year, Google will launch GooglePlex, a banking app integrated with Google Pay—creating a single app to pay businesses and peers, manage savings, and conceivably even apply for loans.

## DISRUPTIVE IMPACT

As physical cash declines and banks and retailers depend on big tech to facilitate transactions, competition is intense. Tech companies enjoy revenue streams and rich personal data about people's spending habits for use in predictive marketing. That data may soon be worth more than the currency itself. Consumers pay twice: first with money, then their personal data. WeChat and Alipay drive China's advanced fintech economy with a network of merchants that accepts chat payments, blurring the lines between payments to friends and stores. As U.S. and European Union regulators debate whether to keep big tech out of finance, expect more stringent regulation in the wake of data breaches, privacy concerns, rampant fraud, and antitrust claims. Are platforms becoming banks? Or are banks plugging into platforms? Either way, radical digital transformation is happening across the financial services industry.

## EMERGING PLAYERS

- Affirm
- Ant Group
- Baidu
- Green Dot



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## A New Bretton Woods

### Mid-future neutral scenario

In 1944, 44 allied nations met in Bretton Woods, New Hampshire, to map out international monetary regulations and financial policies post-World War II. In addition to establishing the International Monetary Fund, they also created a fixed foreign exchange market and set the U.S. dollar as the global reserve currency. While fixed foreign exchanges are a thing of the past, the hegemony of the U.S. dollar remained intact, allowing the United States to borrow at lower interest rates and giving Americans the ability to import goods with higher purchasing power. Given what we know about digital currencies, inflation rates, and global trade, a new global summit is held to reimagine international monetary policies or displace the U.S. dollar. This "sequel" to Bretton Woods builds on John Maynard Keynes' idea, proposed at the original summit in 1944, for a "bancor," a supranational currency for global trade. Thanks to existing modern technology that allows for such a currency to be pegged to a basket of assets, and ensures that no single country has a dominant financial advantage on the world stage, Keynes' dream of a bancor is finally made reality.

# Scenarios



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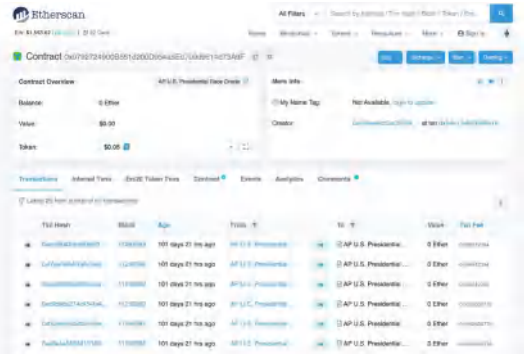
3RD YEAR ON THE LIST

# Content Provenance and Permanent Archiving




The Associated Press posted verified election results from the 2020 U.S. presidential race on the Ethereum blockchain.

## KEY INSIGHT

**Blockchains can be used as a universal index of content authorship and edits. This is a powerful tool to authenticate content and to combat censorship and misinformation.**

## EXAMPLES

Blockchain can permanently archive content that would otherwise be subject to censorship or suppression. After censorship by social media sites like 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. People in China and Turkey also use 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. In 2020, the Associated Press used Ethereum blockchain to post verified results from the U.S. presidential race, and The New York Times may use the technology to combat misinformation. The News Provenance Project traces the origins of journalistic content and detects doctored or manipulated images and videos.

## DISRUPTIVE IMPACT

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. Expect more blockchain experimentation for verifying original online content and its origins, and for more secure archiving. This is key: The decline of internet freedoms globally over the past decade means more internet censorship, more media manipulation, and less access to information. In an increasingly digital world, small newsrooms and large media companies struggle to maintain permanent archives.

## EMERGING PLAYERS

- Associated Press
- Internet Archive
- New York Times
- InterPlanetary File System



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8TH YEAR ON THE LIST

# Automated Credit Risk Modeling

Root Auto Insurance uses the accelerometer in mobile phones to assess customers' driving and issue an insurance quote accordingly.

## KEY INSIGHT

**Banks and insurance companies are using artificial intelligence to automate credit risk modeling.**

## EXAMPLES

Spin Analytics is a fast-growing startup that uses predictive analytics, artificial intelligence, and machine learning techniques to forecast credit behavior, future costs, and credit losses of both customers and entire credit portfolios. It's just one example of the AI-powered automated credit risk modeling services being studied and tested at commercial banks, including BBVA and Crédit Agricole. Similarly, Root Auto Insurance issues auto quotes by analyzing customers' driving based on the accelerometer in their mobile phones.

## DISRUPTIVE IMPACT

In many cases, using AI in credit modeling has increased bias against marginalized groups. However, automated processes based on behavior, and not demographics, could result in more just and equitable outcomes.

## EMERGING PLAYERS

- BBVA
- Crédit Agricole
- Genpact
- Spin Analytics
- RapidRatings
- Root Auto Insurance



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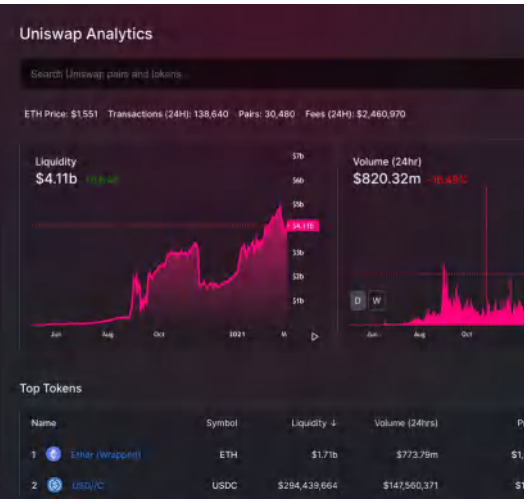
1ST YEAR ON THE LIST

# Decentralized Exchanges and Automated Market Makers




**Uniswap, with more than $1 billion in liquidity, is one of the most recognizable decentralized exchanges.**

## KEY INSIGHT

**Crypto-currency developers have created software to decentralize the exchange process, allowing individuals to trade directly with one another, without relying on a centralized third party to determine prices and settle the trades. Automated market maker algorithms make these decentralized exchanges work.**

## EXAMPLES

Centralized markets like the New York Stock Exchange or Nasdaq maintain fair, consistent, and transparent processes for publishing prices and orders, where market makers provide liquidity with both buy and sell positions. In crypto-currencies and fully electronic markets, algorithms typically price assets, rather than traditional market books. Ethereum-based decentralized exchange Uniswap surpassed $50 billion in lifetime volume, despite concerns about liquidity and volume from darknet markets. Just months after its 2020 start, Curve.fi hit more than $47 billion in volume and became a decentralized finance leader. Total trading volume for these exchanged ballooned to $6 billion as of the first half of last year, up from $2.5 billion in 2018 and 2019.

## DISRUPTIVE IMPACT

Both of these trends—decentralized exchanges and automated market makers—are part of a larger wave of decentralized finance or DeFi. Although it is unlikely to disrupt traditional markets in the short term, there will be a greater demand for modern, impartial, secure systems to settle trades and transactions as more aspects of the global financial system are digitized. Expect bugs, bubbles, and user experience hurdles ahead, because it's the early days of decentralized exchanges and automated market makers. Still, the underlying innovation in finance is undeniable, and it will have lasting impact.

## EMERGING PLAYERS

- Uniswap
- Curve
- Compound
- 0x
- Kyber
- dYdX



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3RD YEAR ON THE LIST

# Web 3.0

The InterPlanetary File System is a peer-to-peer hypermedia protocol that facilitates decentralized file sharing and cloud computing.

## KEY INSIGHT

**Web 3.0 allows for web browsers and mobile applications to perform more complex processes and enable entirely new kinds of transactions. In this new iteration of the internet, individual users would potentially have more autonomy and control of their privacy and data.**

## EXAMPLES

Collaboration and decentralized creation is accelerated in Web 3.0—often referred to as the semantic web. Advanced techniques in data mining, natural language processing, and text analytics will make gathering and understanding unstructured data much easier. Plus, artificial intelligence and machine learning allows machines to collaborate directly with one another and, eventually, teach one another. In media, Otoy is cutting the costs of 3D visual effects production with a decentralized, distributed network of partners that can chip in spare processing power with a digital token known as RNDR. The InterPlanetary File System, a peer-to-peer hypermedia protocol, facilitates decentralized file sharing and cloud computing. Companies like Blockstack and Cosmos are building networking products that will unlock a new generation of applications and services.

## DISRUPTIVE IMPACT

The world wide web celebrated its 30th anniversary in 2019. Decentralization and collaboration are driving its next iteration. Smart cities, Internet of Things, and AI-enabled tools are simply not 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.

## EMERGING PLAYERS

- Blockstack
- Cosmos
- Lightning Labs
- RSK
- The International Political Economy Society



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4TH YEAR ON THE LIST

# Smart Royalties

Blockchain networks like Ethereum offer new ways to track ownership.

## KEY INSIGHT

**Blockchain networks like Ethereum offer new ways to track ownership, licensing, and royalties through smart contracts, or self-executing agreements in which the terms are directly written into lines of code. Blockchains form the foundational infrastructure layer for new, low-friction ways to automate royalty payments for digital intellectual property.**

## EXAMPLES

A smart contract, for instance, could 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. Blockchain is at the core of the Open Music Initiative (OMI)—made up of IBM, Netflix, Pandora, and Spotify—which is developing a standardized open-source protocol and APIs for the music industry. OMI launched a pilot with Massachusetts Institute of Technology that lets Berklee College of Music students license their work to other universities. Media organizations may use smart contracts, digital intellectual property rights structures, and micropayments—potentially revisiting the 1980s CompuServe economic model in which readers paid per view for high-quality journalism articles and images. It failed upon the arrival of free high-quality journalism online.

## DISRUPTIVE IMPACT

Digital asset ownership is evolving in favor of content creators holding the rights to their content. Europe's GDPR law gives ownership rights to data that people create, no matter the platform. Expect more platforms to embrace this ownership model and compensate creators—musicians, photographers, videographers, writers—for driving engagement. Today, Instagram doesn't pay content creators; instead, brands pay to gain access to their followers. The Impact Musicians may be the first to publish content on platforms with smart contracts without management and distribution companies. It may succeed, due to enduring music demand and more artist revenue. News platforms may follow suit with video and photo libraries—but journalists tend to have more elastic followings than other artists. Regardless, creative industries face digital ownership and licensing challenges.

## EMERGING PLAYERS

- Associated Press
- Ethereum
- Mycelia
- Open Music Initiative
- Berklee School of Music



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## Charitable e-Skimming

**Near-future optimistic scenario**

Facing pushback from anti-consumerism groups, the biggest web retailers partner with not-for-profits to make Black Friday and Singles' Day the biggest charitable events of the year. By adding the equivalent of a few pennies to every transaction, and directly routing those pennies in support of altruistic causes, these sites are able to add a feel-good aspect to occasions that are otherwise capitalist bonanzas. The charitable aspect incentivizes purchasing, increasing overall sales, and the cumulative funds raised amount to significant contributions to the partnering not-for-profit organizations—a win-win situation. Shoppers can choose from a list of causes to support for the day, and every purchase they make adds to their total donation—at the end of the event, customers are automatically emailed forms documenting their donations, which can be submitted for tax deductions. Opting to up one's donation unlocks exclusive deals, creating a flywheel that benefits all parties.

# Scenarios



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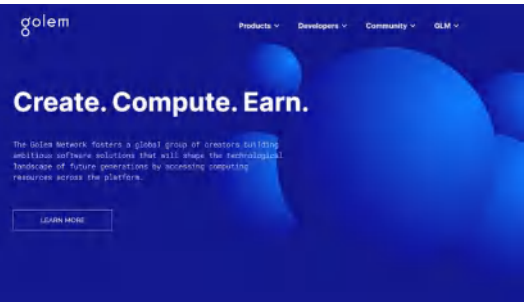
3RD YEAR ON THE LIST

# Distributed Computing for a Cause




The Golem network monetizes your downtime.

## 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, cellphones, and other digital devices to support causes or solve socially relevant problems.**

## EXAMPLES

Folding@Home lets consumers donate idle processing power to fuel disease research via their computers, PlayStation 3s, and some Sony smartphones. In 2020, Folding@Home became one of the fastest computing systems due to increased interest during the COVID-19 pandemic. Since its launch two decades ago, the project has led to 225 scientific research papers. Another project, the Golem network, uses Ethereum blockchain and lets people rent out idle computing resources like storage, processing power, or bandwidth to render computer-generated images, conduct DNA analysis, and tackle machine learning tasks.

## DISRUPTIVE IMPACT

Distributed computing systems will drive down prices for developers and those with greater processing power needs, and they will provide the average device owner with a new source of income and a novel way to support purpose-driven initiatives. Expect to see more platforms that monetize idle computer resources, allowing consumers to earn income from underutilized devices they already own.

## EMERGING PLAYERS

- Amazon Web Services
- Einstein@Home
- Folding@home
- Golem network
- The Great Internet Mersenne Prime Search
- TheSkyNet



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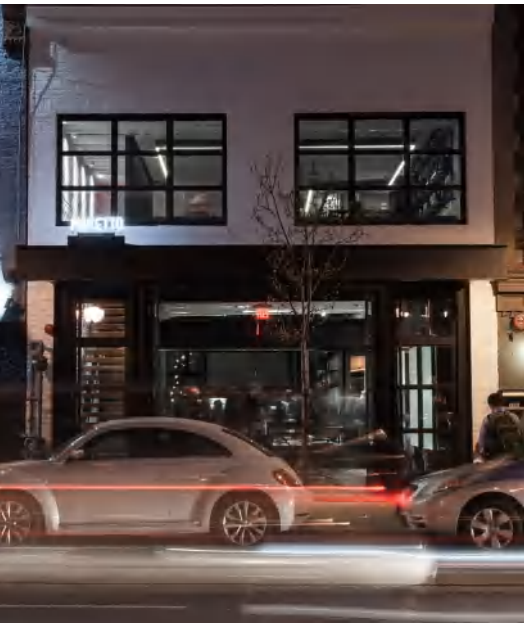
1ST YEAR ON THE LIST

# Fractional Ownership



Maketto in Washington, D.C., is the first crowd-funded real estate project in the United States.

## KEY INSIGHT

**Fractional ownership, commonly associated with time-shares, allows unrelated parties to divide costs and risks in order to collectively own an asset. Now that the concept is being applied to blockchain and digital platforms, it can unlock new ways to purchase and own assets, whether they're in fine art, stocks, or other markets.**

## EXAMPLES

Fintech company Fundrise organized the first crowdfunded real estate development project in the United States. Otis Wealth and Masterworks.io offer fractional ownership for works of art, while Schwab and Robinhood now let investors purchase fractional shares of stocks. Typically registered with the U.S. Securities and Exchange Commission, fractional ownership companies undergo considerable regulatory oversight.

## DISRUPTIVE IMPACT

Fractional ownership democratizes investing. While the sharing economy prioritized access over ownership, people still want 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, we may see an increase in speculative bubbles and economic instability.

## EMERGING PLAYERS

- Commonwealth Bank of Australia
- Ernst & Young
- Fundrise
- MachineryLink Sharing
- Maketto
- Maecenas
- Meridio
- Masterworks
- Otis Wealth
- Property Share
- Roofstock
- Robinhood



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1ST YEAR ON THE LIST

# Self-Funding Digital Infrastructure

Gitcoin, a marketplace for open-source bounties, has funneled $10.6 million to open-source software projects.

## KEY INSIGHT

**Some corporations now "sponsor" developers so that they can dedicate their time to development, and new mechanisms are emerging to enable sustainable digital infrastructure.**

## EXAMPLES

Although much of the internet relies on free open-source software, people are more inclined to use it than maintain it—which is difficult and often leads to burnout of key contributors. Gitcoin, which caters primarily to the Ethereum blockchain community, created a marketplace of bounties for open-source developers who want to contribute to projects and earn income for their work. Since 2017, Gitcoin has facilitated $10.6 million 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 as the crypto is mined—to go toward community development.

## DISRUPTIVE IMPACT

Many crypto-currency and blockchain projects depend on open-source development, and the pioneering of new funding models could result in more sustainable and more robust digital infrastructure.

## EMERGING PLAYERS

- Gitcoin
- Bitcoin
- Ethereum
- Zcash



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1ST YEAR ON THE LIST

# Non-Fungible Tokens and Digital Collectibles

At the height of its popularity, CryptoKitties nearly stalled the entire Ethereum network.

## KEY INSIGHT

**Blockchains enable digital tokens that are provably unique and scarce. As a result, digital collectibles are now a growing feature of eSports, online gaming, and social networks. These unique tokens have a variety of applications—from personal expression to commerce to investing.**

## EXAMPLES

Ethereum-based collectibles game CryptoKitties started in 2017, allowing people to collect, breed, and trade silly looking cartoon cats. Each kitten, a non-fungible token, came with 12 "cattributes," such as fur color to "purrstige." Its popularity nearly stalled the Ethereum network—the priciest kitten sold for $100,000. Its creator, Dapper Labs, launched NBA Top Shot, the Samsung Galaxy store's first blockchain-backed digital collectibles set. Nifty Gateway and Rarible let people buy digital art that's tracked and verified using blockchain. Roblox and Fornite allow gaming players to customize their avatars with digital accessories and skins. People can collect and trade digital versions of luxury brands, such as LVMH and Gucci.

## DISRUPTIVE IMPACT

As more aspects of our lives shift online, demand for digital status symbols and personal expression will increase. Digital collectibles will be portable from one online platform to another, allowing people to create a full picture of their digital selves no matter where they exist online. Already, digital collectibles include personal tokens, which let people tokenize their time, future salary, and even influence over major life decisions. French developer Alex Masmej raised $20,000 in a "human IPO," raising U.S. Securities and Exchange Commission red flags.

## EMERGING PLAYERS

- NBA
- Roblox
- Nifty Gateway
- Rarible
- Gucci
- LVMH
- SuperRare

At the height of its popularity, CryptoKitties nearly stalled the entire Ethereum network, and the most expensive digital kitten sold for more than $100,000.



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## Human IPOs

**Near-future pessimistic scenario**

Are you a good investment? As big tech harvests and monetizes more and more of our data, companies gain a clearer picture of their highest-value users. They begin offering certain users the option to "go public," allowing other users to invest in them with either money or engagement. The platforms tweak their algorithms to give a "listed" user better-than-average exposure and advanced analytics in exchange for a stake in the value the user creates. While the wealthy opt out, those users struggling to make ends meet, as well as those with aspirations to become influential within the platform, can't pass up the opportunity. Generate more value for your tech "brokers," and they'll encourage others to invest in you and raise the price for your data. Behave in ways that don't benefit your benefactors, and you'll watch your value plummet—worse yet, you might get delisted.


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# Application

## STRATEGY

Innovative use cases for blockchain abound, but the complexity of the ecosystem remains a hurdle for most companies. Disorganized experimentation without strategic positioning jeopardizes positive outcomes and returns on investment. Chief strategy officers can develop strategic approaches to blockchain, assessing feasibility, impact, and opportunities to extract value in the near term.

## INNOVATION

Companies interested in blockchain struggle to find meaningful use cases. Chief innovation officers can champion companywide ideation to identify value, brainstorm new use cases, test desirability and feasibility, create proof of concepts with paper or functional prototypes, and launch new pilots—with systems to collect data, test, and evaluate applications. Within many organizations, blockchain enthusiasts are hiding in plain sight, ready to contribute to new initiatives.

## R & D

There is a shortage for R&D funding outside of the largest financial institutions. Grants can advance blockchain technology, but government agencies, university initiatives, and a handful of big payment companies will provide most funding. More work is needed: researching bitcoin's long-term economic security, and addressing the protocol risks of crypto-currencies and deep code reviews. There is an opportunity to lead: Companies could both fund and become the initial beneficiaries of blockchain research.

## RISK

In the longer term, as smart contracts and blockchain peer-to-peer frameworks gain acceptance, business models must transform. Blockchain will reduce operational costs and increase efficiencies. Human-based trust models will transition to algorithmic ones, potentially exposing companies to new risks. Data hygiene and governance, algorithm explainability, and blockchain controls will be paramount in this new environment.



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# 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 about blockchain, crypto-currencies, and regulation:

1

**How will blockchain drive efficiency in our business practices and drive new innovation in our industry?**

2

**Are we adequately planning for the longer term?**

**What assumptions must hold true for our current strategy to succeed?**

3

**What parts of our business model make us vulnerable to disruption brought by the evolution of blockchain?**

**What can we do now to mitigate future risk?**



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Volume 10 of 12

14th Annual Edition

# 2021 Tech Trends Report

Strategic trends that will influence business, government, education, media and society in the coming year.

5G

Robots

Transportation

Future Today Institute

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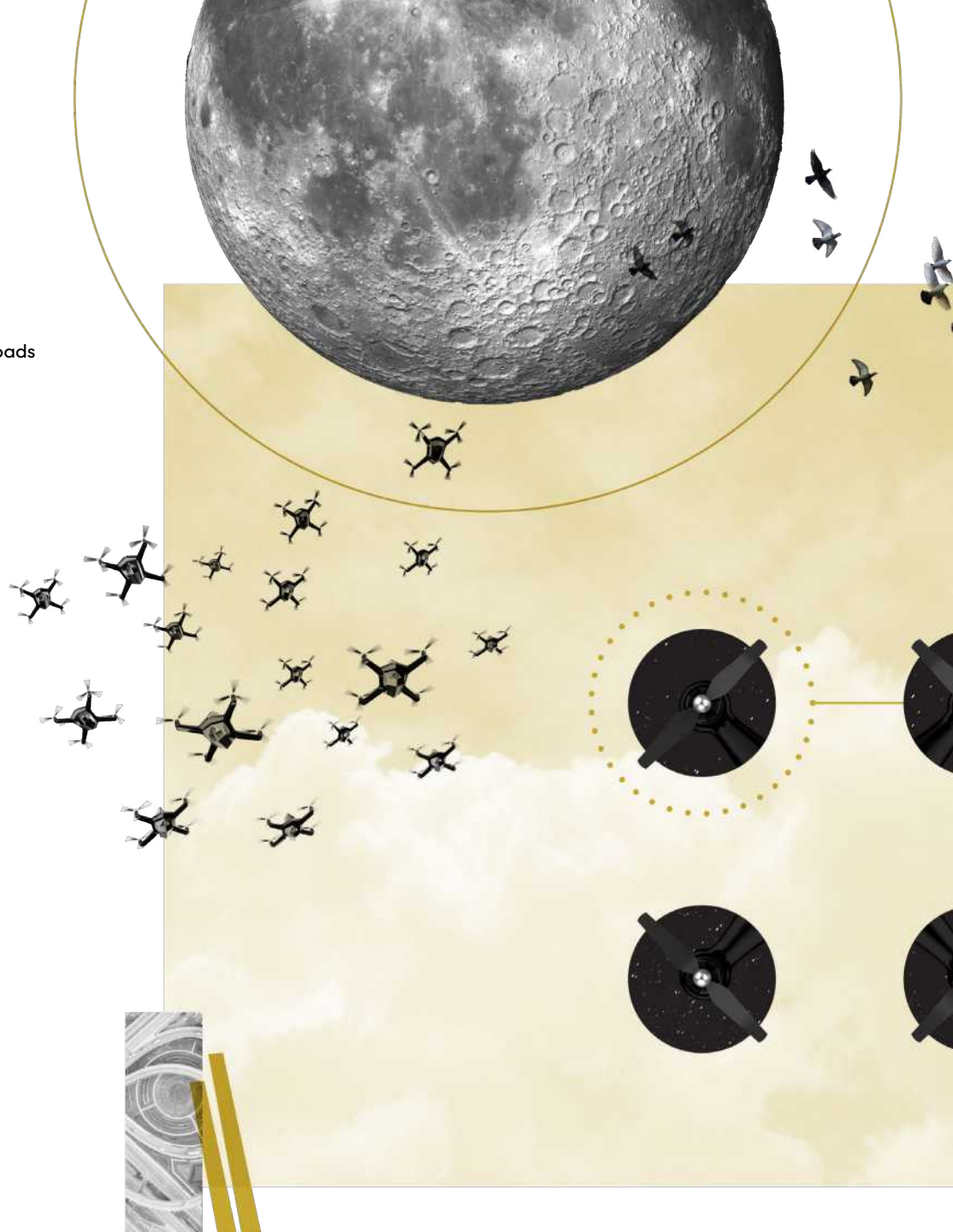

# 5G Robots & Transportation Summary

- 6G will be the sixth generation of wide-area wireless technology, following the transition to 5G. Planning for this new standard is already underway.
- A new standard for latency is in the works and could break the millisecond barrier.
- The global quantum computing race is on, and equity deals for quantum computing startups surged in 2020.
- There will be millions of implementations of robots-as-a-service over the next five years, which could generate billions of dollars of revenue.
- As 5G comes online and reduces latency, robots will process spatial data at fast enough speeds to adapt to environmental changes.
- Robots are now capable of "sweating" thanks to a soft, robotic muscle that can autonomously regulate its internal temperature, just like living organisms do.
- Robotic dogs specially designed for Mars will travel in packs and assist each other as they climb, jump, and descend new terrains.
- Some governments will consider granting the legal status of "electronic persons" to sophisticated robots.
- Construction materials such as bricks could soon behave like human cells and evolve, replicate, and assemble organically with others.
- China is creating a new mobility ecosystem that includes electric vehicles, apps, communications systems, artificial intelligence, and data, and it is intending to ship its products to the West.
- Saudi Arabia is developing futuristic new megacities. They will have advanced technologies and urban ecosystems that rival every other major city.
- Efforts are underway to create fully autonomous, AI-powered ships, along with a legal framework for them to operate safely and officially in international waters.



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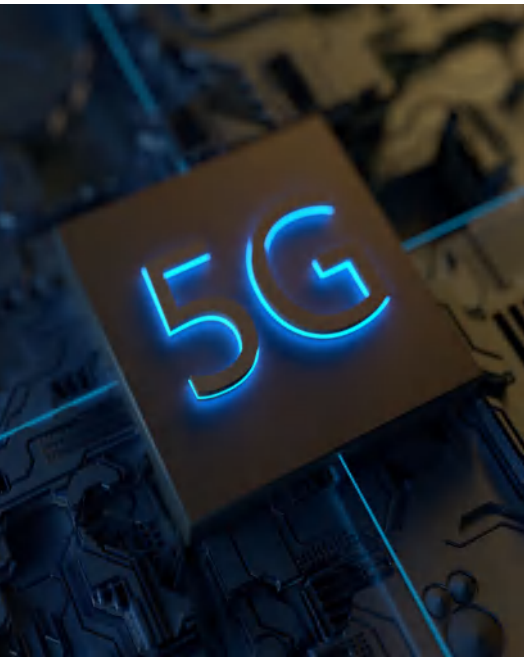
# 5G

4TH 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. Since the first 5G mobile networks began launching in 2019, this new standard has rolled out slowly around the world. Eventually, 5G will offer higher speeds, low or even no latency in data transfer, and the ability for billions of devices to connect with one another.**

## EXAMPLES

5G advances today's networks using a more responsive kind of radio technology that not only moves data faster but also requires less power to do so. It will shorten transmission latency from 30 milliseconds to just a single millisecond, allowing essentially instantaneous connectivity between devices on a network. This means big opportunities for telemedicine and robotic-assisted surgery, autonomous vehicles, gaming, and streaming. Unlike Wi-Fi, a 5G network can be built to prioritize certain data transmissions over others. For example, heavy manufacturing companies and utilities will be able to automate more of their core processes using advanced robotics systems, which will in turn create a new market for all the components, devices, and consulting services necessary for operating such a network.

## DISRUPTIVE IMPACT

Monetizing 5G remains a challenge for mobile network operators (such as Verizon, Vodafone, and Telefónica), which must gradually make network improvements while continuing to provide service for previous 3G and 4G standards. This last mile of the telecom ecosystem is the most complex and costly to maintain, and earns revenue mainly through customer plans. South Korea launched high-value, premium 5G plans to increase revenue alongside new products and services to entice adoption. VR cloud gaming, augmented reality shopping, and live sports streaming are bundled in new premium plans. South Korea notwithstanding, most 5G launches still lack the use cases needed to convert users and justify the investment in network upgrades. In the U.S., the Federal Communications Commission created two Innovation Zones, city-scale test beds in Salt Lake City and in New York City's West Harlem, for advanced wireless communications and network research, including 5G networks.

## EMERGING PLAYERS

- National Spectrum Consortium
- 5G Fund for Rural America
- Open Radio Access Network (O-RAN)
- Spectrum Forward Other Transaction Agreement
- U.S. Department of Defense's Research and Engineering Division



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4TH YEAR ON THE LIST

# 5Geopolitics

Huawei is a major supplier of network components.

## KEY INSIGHT

**There's a geopolitical fight underway, pitting the U.S. against China in a race to deploy the telecom equipment and systems required to build 5G networks.**

## EXAMPLES

The Trump administration tightened the screws on China when it banned Chinese companies ZTE and Huawei from supplying gear to American network operators in the U.S. Chipmaker Qualcomm, meanwhile, is one of a scant few U.S. companies making components necessary for a widescale 5G rollout. Trump revoked licenses to Huawei suppliers, which included Intel, and thereby weakened the Chinese tech giant's position in the global market. American security experts are urging the Biden administration to build a 5G network with and for geopolitical allies and to exclude Chinese equipment. As of this writing, only Ericsson, Nokia, and Samsung are allowed to build 5G networks in the U.S. Meanwhile, Chinese President Xi Jinping has made it clear that he intends to wean China and its allies off of Western-made technology entirely.

## DISRUPTIVE IMPACT

New entrants are circumventing politics. Japanese e-commerce giant Rakuten launched a virtual network running on cloud native and open radio access network (O-RAN) technology. The network architecture costs far less to build and operate, and doesn't rely as much on equipment from traditional suppliers. Elon Musk's Starlink is developing a low-latency broadband internet system with speeds of 300Mbps—fast enough to manage Wi-Fi calling and just about anything else consumers might stream, play, operate, or build.

## EMERGING PLAYERS

- Semiconductor Industry Association
- Open Radio Access Network (O-RAN)
- Rakuten Mobile
- Starlink



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# Expert Insight

## 5G Will Transform Transportation, Entertainment, Retail and More

**Igal Elbaz**

SVP of Wireless and Access Technology, AT&T

A little more than 25 years ago, AT&T debuted a bold advertising campaign predicting a future world enabled by emerging technologies. At the time, the ads mimicked science fiction—video calls from a payphone, sending a fax on the beach and talking to a friend on a watch. While the experiences look different than our predecessors imagined, they are now realities and even necessities, as 2020 pivoted the needs of our customers and forced transformation across all industries.

What can we accomplish in the next five, 10 or 25 years? Innovation is happening at the speed of 5G, and the next wave of bold predictions is well on its way.

5G will ultimately be a paradigm shift from prior networks. The increased speeds, lower latency and higher reliability will create the ideal foundation for transformational use cases. The ecosystem is developing capabilities never before imagined with LTE. There's no better time than now to take a visionary approach to the possibilities. We're collaborating with customers and allies to identify how technology can create a safer, more connected world.

Take the healthcare industry, for example. The combination of 5G,

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> There's no better time than now to take a visionary approach to the possibilities.

edge computing, artificial intelligence (AI), and Internet of Things unlocks a new realm of possibilities for medical professionals. Last year, 2020, triggered the rise of telehealth, and this momentum will only continue. Faster speeds, lower latency, and massive connectivity will enable more real-time remote consultations, crucial data transfers, and connected ambulances. As 5G matures, we'll see the advancement from today's telemedicine and remote consultations during surgery to robotic-assisted surgeries and development of life-saving wearables.

5G is also paving the way for the future of transportation. At the AT&T 5G Innovation Studio in Plano, Texas, we're working with collaborators to showcase how 5G and edge computing can enable autonomous drones. And, as the edge expands, self-driving cars will eventually become ubiquitous, creating safer roadways. Flash forward even further, and you could be looking toward the sky for a flying taxi.

Today's technology will also transform the retail world, because 2020 shifted how we shop. There could be "magic mirrors," or connected displays, that use 4K sensors and digital displays to replicate the experience of standing in front of a mirror. Instead of having to physically try on clothes, consumers could swipe left and right to try on outfits and accessories. Then, using a connected tablet, an employee could place the order, and the clothes could be on a customer's doorstep in 48 hours. This will become a widespread reality that many retailers are expected to embrace.

Another exciting area of opportunity is the entertainment industry. 5G is already re-imagining how we create and consume media in this new world. Holographic communication proved useful during last year's NBA playoffs when reporters were able to perform holographic interviews with players from hundreds of miles away, a necessity given restrictions around in-person interviews.

Now, imagine holographic communication for the masses. In the not-so-distant future, we could enjoy live, immersive concerts from the comfort of our couch. And, we've taken the initial steps toward this reality. AT&T recently used 5G, machine learning, and edge computing to deliver a live 3-D augmented reality interactive concert for a select group of fans. Entertainment will become more immersive with the advancement of AI and edge computing, and we'll eventually blur the divide between the physical and digital world.

5G is triggering the next wave of business transformation and industrial revolution, and these use cases are only a glimpse of what's on the horizon.

**

*Igal Elbaz is senior vice president of Wireless and Access Technology. He is responsible for wireless and wireline access network architecture, design and technology roadmap, including radio access network, 5G and LTE mobility, voice core network functions, network AI and driving industry standards.*



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4TH YEAR ON THE LIST

# 6G

Hexa-X is developing standards for 6G.

## KEY INSIGHT

**6G will be the sixth generation of wide-area wireless technology, following the transition to 5G. Planning for this new standard is already happening.**

## EXAMPLES

Project Hexa-X, the European Commission's early 6G research initiative, kicked off in January 2021 in preparation for the global standard that comes after 5G. The current global transition from 4G to 5G is a tricky one: There are lots of variables over which no one entity has control. Core components—licensed and unlicensed spectrum bands, shared spectrum, antennas, and network architectures—aren't necessarily uniform. Experts believe that what they learn building 5G networks will make the transition to 6G easier. Researchers at the University of California, Santa Barbara, are already working on component upgrades: They built a device that could push 6G's terahertz frequency signals out of antennas using what's known as an N-polar gallium nitride high-electron-mobility transistor (HEMT). Nokia is leading the 6G joint research initiative, and Nokia Bell Labs is already researching the fundamental technologies that will comprise 6G.

## DISRUPTIVE IMPACT

6G should support data rates of 1 terabyte per second, making latency and capacity balancing a thing of the past. This new standard will support technologies that demand real-time awareness—which are likely to include human-machine interfaces that intuitively understand our intentions. Combined with artificial intelligence, the new infrastructure of 6G will make networks capable of making decisions autonomously for things like data storage, processing, and sharing.

## EMERGING PLAYERS

- Hexa-X
- Nokia
- Next G Alliance
- University of Oulu
- University of Padova
- Beijing University of Posts and Telecommunications
- NTT DoCoMo
- Samsung
- Ericsson
- Huawei
- ZTE



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1ST YEAR ON THE LIST

# Breaking the Millisecond Barrier

A new 1 millisecond standard is being developed.

## KEY INSIGHT

**The amount of latency in mobile networks differs, based on how far a signal must travel, the number of routers it passes through, and a variety of other factors. A new standard for latency is in the works that could result in just 1 millisecond of lag.**

## EXAMPLES

Latency causes problems in gaming, videoconferencing, and VR. A typical 4G network incurs 50 milliseconds of lag, and with more devices and people connecting to networks, systems can quickly become glitchy. As people worked and learned from home during the pandemic, signals weakened, causing interruptions or crashes. The coming swarm of signal-hungry consumer devices will put added strain on networks, unless current latency barriers can be broken. Reducing latency from 4G's 50 milliseconds to 5G's 10 milliseconds and below will be crucial to support applications such as autonomous vehicles and multiplayer games.

## DISRUPTIVE IMPACT

A new 1 millisecond standard is being developed at New York University's NYU Wireless research center. It will require a new approach to encoding, transmitting, and routing data—but it also promises a wild new frontier in communications. If signals transmit fast enough that humans can't perceive any lag at all, teleoperated surgical robots could go into widescale use. Haptic devices that map sight and sound could convince us that a digital environment is real, not virtual.

## EMERGING PLAYERS

- NYU Wireless
- Internet Engineering Task Force's L4S
- U.S. Department of Defense



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# Edge

4TH YEAR ON THE LIST

# Edge Computing

Snowcone is used to run edge computing workloads, or to collect, process, and transfer data to Amazon Web Services.

## KEY INSIGHT

**Edge computing performs computations near or at the source of data.**

## 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. The challenge for existing cloud-based computing environments is the potential for delay, which is also known as latency.

## DISRUPTIVE IMPACT

In the near future, more of the computational work could be done locally—for example, a car's computer vision system would process and recognize images immediately rather than sending that information to the cloud for verification. Edge computing requires custom chips and hardware, and will work alongside the cloud rather than replace its functionality. Consumer devices that perform biometric recognition and authentication—from smartphones to smart toilets—will rely more on the edge to shore up privacy and security.

## EMERGING PLAYERS

- Open Neural Network Exchange
- AWS Snowcone
- AWS IoT Greengrass
- Nvidia's EGX AI
- IBM's Edge Ecosystem



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# Edge Computing Trends

Edge computing is accelerating and will impact data centres and cloud expansion in 2021.

## Near-real-time Application Environments

Within the next decade, there could be as many as 50 billion devices online generating enormous amounts of data. Edge computing is closely tied to the Internet of Things and 5G connectivity. As virtual reality and extended reality become popular, more processes will be pushed onto headsets. For example, AWS IoT Greengrass, the platform for extending Amazon Web Services to edge devices, was created to more easily deploy applications.

## AI at the Edge

With the proliferation of smart cameras and speakers, developers are building edge systems that can recognize natural language, people, pets, and objects. Open standards, such as the Open Neural Network Exchange (ONNX) are making on-device machine learning easier, while TensorFlow Lite and TinyML encourage artificial intelligence at the edge. Nvidia's EGX AI platform for edge computing features an extensive range of software accelerated by GPUs (graphics processing units). This includes Helm Charts (collections of files) for deployment on Kubernetes, or portable, open-source systems for managing "containerized" work and services. It also gives users access to third-party, domain-specific, pretrained models and Kubernetes-ready Helm Charts that make it easy to deploy software or build customized solutions.

## Edge Management

Because data and applications now live in many places-individual devices, the cloud, local storage—a traditional, one-size-fits-all approach to monitoring won't work. Instead, new processes will be required to help manage the overall digital experience, from security risks to latency and bandwidth.

## Big Tech Companies at the Edge

AWS invested $29 billion in its edge computing project Snowcone. Part of the AWS Snow Family of edge computing, edge storage, and data transfer devices, Snowcone is designed to fit inside a messenger bag. The edge computing device collects and processes data locally. For example, a Snowcone device could sit inside a manufacturing center, collect and analyze data from a production line, and gain insights from AI systems built into the AWS ecosystem. Microsoft is integrating edge capabilities with Azure, while IBM's Edge Ecosystem is an open standards–based cloud native solution that can be deployed and autonomously managed at the edge at massive scale.

## Hyper-local Data Centers for Edge Computing

The new streaming services—such as Apple TV+, Peacock, Disney+, HBO Max—are entering a crowded field dominated by Netflix, Amazon, Hulu, and YouTube. But there's a problem looming: compression and bandwidth. As a result, we will need lots of hyper-local data centers positioned closer to consumers. AWS is now building "local zones" close to major cities, with the goal of managing latency-sensitive workloads.



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# Quantum

4TH YEAR ON THE LIST

# Quantum Computing

Google's Sycamore performed a challenging calculation in 200 seconds.

## KEY INSIGHT

**Quantum computing uses the properties of quantum physics to store data and perform computations using specialized machines.**

## EXAMPLES

In short, quantum computers can solve problems that are computationally too difficult for a classical computer, which can only process information in 1s or 0s. In the quantum universe, those 1 and 0 bytes can exist in two states (qubits) at once, allowing computations to be performed in parallel. So, if you build two qubits, they can hold four values at the same time: 00, 01, 10, 11. Scientists have theorized about the possibilities of quantum computing for decades and only built the first working system in 1998. The challenge, however, has been proving that a quantum machine is actually carrying out quantum computations. That's because in a quantum system, the very act of observing information in transit changes the nature of that data.

## DISRUPTIVE IMPACT

Quantum computers are becoming more powerful and available. Equity deals for quantum startups surged in 2020, nearly doubling from the previous year. Most activity is aimed at transforming health care, logistics, and finance. But a persistent fear is driving much of today's research: Quantum computers could break today's encryption protocols at a speed and scale beyond anything we've ever seen.

## EMERGING PLAYERS

- U.K. National Quantum Technologies Programme
- European Union's Quantum Flagship
- U.S. National Quantum Initiative Act
- National Institute of Standards and Technology
- Google AI Quantum
- Rigetti Computing
- IBM Q Network



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# Quantum Computing Trends

Quantum computing could transform the future of security, encryption and national security.

## Updating Post-Quantum Cryptography Standards

U.S. National Institute of Standards and Technology will recommend new guidelines in 2021 to help organizations transition to new cryptography standards. In the U.K, the National Cyber Security Centre published recommendations for any organization using secured transactions. Today's encryption standards could quickly become outdated as quantum computers improve, and the complexity of upgrading IT systems in large organizations will take years to complete.

## Quantum Supremacy

In October 2019, Google researchers published a paper in the journal Nature as well as a blog post on the company's website explaining that they had achieved "quantum supremacy" for the first time. It was a significant revelation. Physicists said that their 53-bit quantum computer, named Sycamore, calculated something that an ordinary computer—even a very powerful one—simply could not have completed. Sycamore performed a challenging calculation in 200 seconds. On the world's current fastest traditional computer, that same calculation would have taken 10,000 years. In February 2021, researchers from Google and quantum computing company D-Wave Systems solved a real-world challenge 3 million times faster than a classical computer.

## Global Quantum Computing Race

The global quantum computing race is underway. Several nations, including the U.S., France, the U.K., and China, want to become the global leader in quantum computing. Governments are setting the stage now to attract talent and investment, ahead of the first real-world quantum use cases. The U.S. passed the National Quantum Initiative Act in 2018, earmarking $1.2 billion for quantum research. Last year, the U.S. launched five new quantum computing centers, including one at the Lawrence Berkeley National Lab to codesign algorithms, quantum devices, and engineering solutions; a center at the Fermi National Accelerator Laboratory to make it easier to deploy quantum systems; and a center at Brookhaven National Laboratory to build new nuclear, chemical, and physics applications. Some would say that the U.S. showed up a day late and a few billion dollars short. The U.K. National Quantum Technology Program kicked off in 2013 and is now in its second phase, with $1.3 billion in investment. Germany's program is funded at $2.4 billion. A team of researchers from the University of Science and Technology of China published a paper in the journal Science describing their quantum computer achieving speeds that were 10 billion (yes, billion) times faster than Google's Sycamore.

## Quantum Boosts for Classical Computers

New kinds of processors are being designed to add on to existing equipment, to give classic computers a quantum boost. The end result isn't a complete quantum computing system, but more of a hybrid. Rigetti Computing is building small quantum processors that integrate with the cloud. Pharmaceutical company Merck is experimenting with the processors for faster drug development and production.



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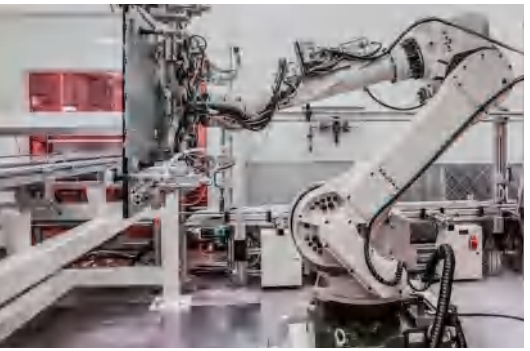
# Robots

3RD YEAR ON THE LIST

# Robots-as-a-Service (RaaS)



Microsoft's partnership with Open Robotics will open the Azure cloud platform to ROS developers.

## KEY INSIGHT

**Cloud robotics and automation is a field in which physical robots share data and code, and perform computations remotely via networks, rather than within their containers alone.**

## EXAMPLES

Autonomous vehicles are robots that use a network to access maps, understand spatial information, and more in order to make decisions. Each vehicle's data is indexed to the network and optimized for further use by researchers and other vehicles. This is an example of cloud robotics, which is used within autonomous driving as well as in warehouse automation and logistics. Amazon's AWS RoboMaker is a cloud robotics service created to develop, test, and deploy intelligent robotics applications at scale. Its partners include Nvidia, Qualcomm, and UP Squared, and it supports the most widely used open-source robotics software framework, Robot Operating System (ROS). Google's Cloud Robotics Core is an open-source platform that provides digital infrastructure essential to building and running robotics solutions for business automation.

## DISRUPTIVE IMPACT

Using the cloud certainly offers advantages: greater efficiencies and opportunities for data sharing and insights, as well as collective learning across robotic networks and shared platforms. Soon, businesses will be able to take advantage of cloud-based robotics for a variety of uses, including strategic warehouse selection in anticipation of seasonal retail spikes, security in large buildings, and factory automation. There will be millions of implementations of RaaS over the next five years, which could generate billions of dollars of revenue.

## EMERGING PLAYERS

- Amazon AWS Robomaker
- Google Cloud Robotics
- Fetch Cloud Robotics



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4TH YEAR ON THE LIST

# Cobots

Cobots are used in a variety of settings.

## KEY INSIGHT

**Collaborative robots—or cobots—work alongside humans or together with other machines. Teams of robots can communicate with one another about when to wait, when to move, when to carry out an activity, or even to ask what to do next.**

## EXAMPLES

Collaborative robots are finding more widespread use in industrial settings, which can often prove challenging for humans alone. ABB's YuMi is a cobot that works alongside humans, assisting with repetitive tasks. In China, automotive components supplier Hella uses YuMi to help workers assemble parts. Comau's Advanced Use Robotic Arm (AURA) is a high-payload cobot that combines vision technology, laser area scanners, and a touch-sensitive tactile skin that allows it to slow its speed and force when it comes into contact with a human operator.

## DISRUPTIVE IMPACT

As 5G comes online and reduces latency, cobots will process spatial data at fast enough speeds to adapt to environmental changes. Today, collaborative robots make up just 3% of the current installed robot base around the world, but that's going to change. According to the International Federation of Robotics, collaborative robots are the fastest growing segment of new robot sales.

## EMERGING PLAYERS

- Massachusetts Institute of Technology's Interactive Robotics Group
- Sapienza University of Rome
- Johns Hopkins Applied Physics Laboratory
- Karlsruhe Institute of Technology



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3RD YEAR ON THE LIST

# Autonomous, Programmable Robot Swarms

Robot bees could be the future of agriculture.

## KEY INSIGHT

**Autonomous robot swarms are coordinated and distributed to perform complex tasks in a more efficient way than a single robot or non-networked group of robots could.**

## EXAMPLES

Researchers at Harvard University's Wyss Institute are experimenting with different form factors drawn from nature. They developed robots that can autonomously drive interlocking steel sheet piles into soil. In the future, robots like these could be used to build retaining walls or check dams for erosion control. Another project, called Kilobots, involves 1,024 tiny robots working collectively to self-assemble and perform a programmed task. Walmart filed a patent for robot bees, which would work collaboratively in teams to pollinate crops autonomously. If the project works at scale, it could potentially counterbalance the effects of the world's honeybee population decline.

## DISRUPTIVE IMPACT

The possibilities are staggering: Autonomous robot teams could be used to inspect dams and bridges, build complicated 3D structures, and lay protective barriers in the case of toxic chemical spills—freeing up their human counterparts and keeping them out of harm's way.

## EMERGING PLAYERS

- Academy of Opto-Electronics at the Chinese Academy of Sciences
- Wyss Institute at Harvard University
- Amazon Robotics



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3RD YEAR ON THE LIST

# Self-Assembling Robots

M-Blocks are tiny, cube-shaped wheeled robots with sensors and cameras.

## KEY INSIGHT

**A new generation of robots can now self-assemble, merge, split, and repair themselves.**

## EXAMPLES

Massachusetts Institute of Technology developed a set of robots called M-Blocks that use a barcode system to communicate. They can identify each other and move as needed to perform designated tasks, which at the moment include forming a straight line and moving down a pathway. The Modular Robotics Laboratory at the University of Pennsylvania developed SMORES-EP robots—tiny, cube-shaped, wheeled robots with sensors and cameras. Moving independently and docking with nearby modules, they can form different structures and even self-assemble to lift objects and drop them off. They also created Variable Topology Trusses, a new class of robot that can quickly reconfigure itself.

## DISRUPTIVE IMPACT

Self-assembling robots offer a host of possibilities for medicine, manufacturing, construction, and the military. The MIT Computer Science and Artificial Intelligence Laboratory built a self-assembling robot called Primer that is controlled by magnetic fields. It can put on exoskeleton parts to help it walk, roll, sail, or glide better, depending on the environment. Researchers at Georgia Institute of Technology and China's Peking University discovered a new technique that mimics automatic origami—in initial testing, structures could fold and unfold on their own using inexpensive liquid polymers and LED projector bulbs. Self-assembling robots will be tremendous assets in emergency response situations. Imagine a set of robots forming a temporary staircase to rescue someone from a burning building, or a set of bots that can lock together to form a bridge over flooded roads.

## EMERGING PLAYERS

- The Modular Robotics Laboratory at the University of Pennsylvania
- MIT Computer Science and Artificial Intelligence Laboratory



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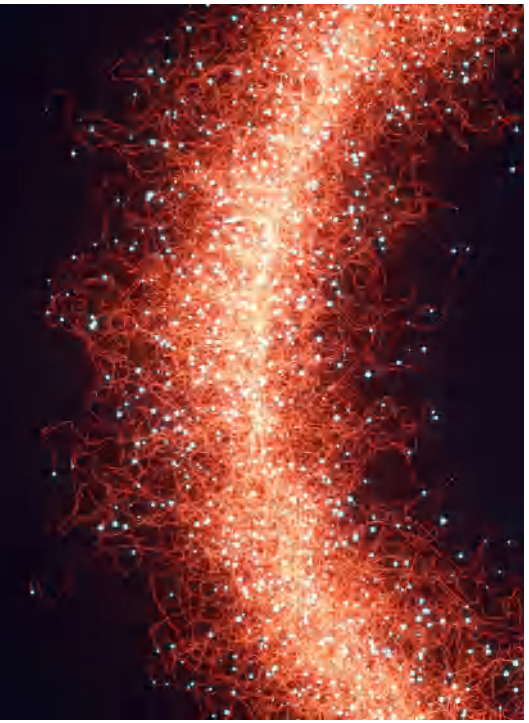
4TH YEAR ON THE LIST

# Robot Compilers



Advanced compilers will supercharge robot fabrication.

## KEY INSIGHT

**We will soon tell computer systems what tasks we need completed, and they will automatically fabricate new robots for the job. Robot compilers would offer greater efficiencies, big cost savings, and increased production for manufacturers in every industry.**

## EXAMPLES

Today, the process of designing, programming, and building robots is time-intensive—and the robots' capabilities are limited by original specifications. In the future, advanced compilers will enable much faster conceptualization and fabrication for a host of different tasks.

## DISRUPTIVE IMPACT

Researchers from the Laboratory for Embedded Machines and Ubiquitous Robots at the University of California, Los Angeles; MIT Computer Science and Artificial Intelligence Laboratory, University of Pennsylvania; and Harvard University are developing new methods for rapid robot fabrication. 3D robotic systems can now be produced using basic software and programmed using natural language commands. 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

- MIT Computer Science and Artificial Intelligence Laboratory
- Laboratory for Embedded Machines and Ubiquitous Robots at the University of California, Los Angeles



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5TH YEAR ON THE LIST

# Soft Robotics

**This robot snake would investigate disasters.**
Image credit: Worcester Polytechnic Institute.

## KEY INSIGHT

**Soft robotics are created to mimic living organisms. Made of flexible materials, they move in fluid ways and adapt in real time to their surroundings.**

## EXAMPLES

Researchers at Worcester Polytechnic Institute created a robotic snake that could navigate through rubble or confined spaces. Bioengineering researchers at the University of California, Los Angeles, developed a tissue-based soft robot that mimics the biomechanics of a stingray. Scientists at the BioRobotics Institute Sant'Anna School of Advanced Studies in Italy created a robot octopus, capable of emulating the animal's agile motions. To replicate the biology of an octopus, they built computer models using exact measurements and then experimented with a number of soft actuators to develop artificial muscles.

## DISRUPTIVE IMPACT

Massachusetts Institute of Technology engineers created soft and compact 3D printed structures that can be guided using magnets. The hope is that they can someday help control biomedical devices, take images within the body, clear arterial blockages, deliver targeted drugs to specific body parts, or even extract tissue samples. Researchers at Cornell University developed a robot capable of "sweating." They built a soft robotic muscle that can autonomously regulate its internal temperature, just like living organisms do. Someday soon, soft robotics will let us enter and explore environments previously unreachable by conventional methods: deep ocean waters, the terrain of Mars, and perhaps even the gushing rivers of blood inside our own bodies.

## EMERGING PLAYERS

- Harvard Biodesign Lab
- Sant'Anna School of Advanced Studies
- University of California, Los Angeles, Samueli School of Engineering
- MIT Computer Science and Artificial Intelligence Laboratory's Soft Contact Modeling Group
- Worcester Polytechnic Institute



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4TH YEAR ON THE LIST

# Smart Dust

The Defense Advanced Research Projects Agency's miniaturized "laboratories on a chip" were developed to detect biological weapons in the field, among other uses.

## KEY INSIGHT

**Smart dust, also known as microelectromechanical systems or MEMS, represents a new way of atomic-level materials engineering.**

## EXAMPLES

If you watched the "Arkangel" episode of "Black Mirror" (season four), you're already familiar with smart dust. For years, researchers have been hard at work on miniaturization, trying to shrink computers as much as possible, down to the size of grains of sand or specks of dust. Each particle-computer consists of circuits and sensors capable of monitoring the environment, and even taking photographs. They can also harvest energy while suspended, using passive Wi-Fi and human body heat to power themselves.

## DISRUPTIVE IMPACT

It sounds fantastical, but the use of MEMS is becoming more common. They're the accelerometer sensors for our airbag systems and are also found in biosensors. Scientists at the University of California, Berkeley, developed what they call neural dust, which comprises microscopic computers that work alongside remote ultrasound to send and receive data about the brain. Meanwhile, researchers at the University of Stuttgart figured out how to print tiny 3D lenses—120 millionths of a meter in diameter, or about the size of a fine grain of sand. In health and medicine, this technology will dramatically change our approach to imaging. Rather than relying on our current endoscopic technology, which is bulky and invasive, a patient could simply inhale smart dust. Beyond medicine, trillions of smart dust particles could be released in the wind to measure air quality or take photos.

## EMERGING PLAYERS

- University of Southern California Robotics Research Lab
- CardioMEMS
- The Center for Advanced Materials Processing at Clarkson University
- Whitesides Research Group at Harvard University
- Center for Research in Advanced Sensing Technologies and Environmental Sustainability at Binghamton University



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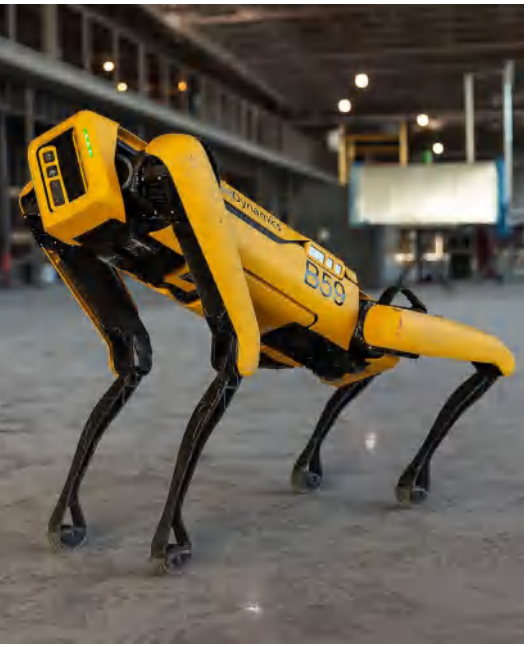
2ND YEAR ON THE LIST

# Commercial Quadrupedal Robots




Spot is a robotic dog from Boston Dynamics.

## KEY INSIGHT

**Quadrupedal robots have four articulated legs and can move around difficult terrain, making them useful tools for inspections and security applications.**

## EXAMPLES

By emulating the form and mobility of four-legged animals, these robots can be deployed in situations that wheeled or tread-equipped robots cannot navigate and that may be too dangerous or physically inaccessible for human intervention. Boston Dynamics started selling a quadruped in October 2019 and released an enterprise model last year. The robot, named Spot, looks like a headless dog and moves with the agility and athleticism of a border collie. Spot can map environments, move around difficult terrain, and interact with a range of different objects. It docks and charges on its own.

## DISRUPTIVE IMPACT

For now, Boston Dynamics is the only company selling advanced robots like Spot for commercial, nonmilitary purposes. The ecosystem is still forming, but as developers build applications across different industries, we expect to see new use cases emerge, particularly in safety, security, maintenance, emergency response, military, and even consumer contexts.

## EMERGING PLAYERS

- Boston Dynamics



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1ST YEAR ON THE LIST

# Mars Dogs

**A robotic dog could someday patrol Mars.**
Image courtesy of NASA/JPL-Caltech.

## KEY INSIGHT

**NASA is working on Mars Dog, a four-legged robot for exploring the red planet.**

## EXAMPLES

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 robotic dog created by Boston Dynamics. Au-Spot, as it is known, is built for Mars: It has AI 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.

## DISRUPTIVE IMPACT

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 unfamiliar terrain on Mars.

## EMERGING PLAYERS

- NASA Jet Propulsion Laboratory
- NASA Ames Research Center
- McGill University
- Boston Dynamics



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5TH YEAR ON THE LIST

# Ethical Manufacturing

Workers at a garment factory in Southeast Asia.

## KEY INSIGHT

**Robots could bring an end to forced labor and lead a new era of ethical manufacturing.**

## EXAMPLES

Sometimes a $5.99 T-shirt is too good to be true. Unfortunately forced labor is common in places including Uzbekistan, China, and Bangladesh. More humane manufacturing processes in fast fashion and other industries could lead to improved working conditions for millions of people.

## DISRUPTIVE IMPACT

As robots become more affordable and available, they could eliminate unethical practices in manufacturing. But creating more humane work environments could destabilize developing economies. Even with extremely low wages, a workforce can sustain a local economy—when those wages are lost as workers are replaced by robots, the flow of money through the community can go from a trickle to a drought.

## EMERGING PLAYERS

- United Nations Alliance for Sustainable Fashion
- World Fair Trade Organization
- Bluesign Technologies
- Oeko-Tex
- Ethical Trading Initiative



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4TH YEAR ON THE LIST

# Robot Rights

**Children bullied a robot.**

Image credit: ATR Intelligent Robotics and Communication Laboratories.

## KEY INSIGHT

**Some believe that we have moral obligations to our machines, and that robots should have rights.**

## EXAMPLES

Instances of humans bullying or abusing robots have increased. The Human Interaction With Nature and Technological Systems Lab at the University of Washington discovered that children didn't show the same kind of empathy for robots that they do other humans. In the study, 60% of the child subjects thought that a humanoid robot named Robovie-II had feelings—yet more than half of them thought it was fine to lock him in the closet. Researchers at ATR Intelligent Robotics and Communication Laboratories, Osaka University, Ryukoku University, and Tokai University conducted an experiment to measure human empathy toward robots. They deployed Robovie through a mall in Osaka, Japan, without a human minder. If someone walked into the robot's path, it would politely ask the human to move. Adults complied—but children didn't. And if unsupervised, the children were intentionally mean, kicking the robot, yelling at it, and bullying it.

## DISRUPTIVE IMPACT

When it comes to our interactions with robots, what constitutes a moral violation? What rights should robots have, given that so many companies are building smart interfaces and cognitive systems? 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? Answering these questions will become increasingly urgent as robots proliferate in many aspects of our everyday lives.

## EMERGING PLAYERS

- Human Interaction With Nature and Technological Systems Lab at the University of Washington
- ATR Intelligent Robotics and Communication Laboratories



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1ST YEAR ON THE LIST

# Robots as Essential Workers

**Robots retrieved supplies so hospital staff could focus on patient care.**

Image courtesy of Diligent Robotics.

## KEY INSIGHT

**During the pandemic, robots became essential workers.**

Governments need to create national registries of robots. Such a registry would let citizens and law enforcement look up the owner of any roaming robot, as well as learn that robot's purpose. It's not a far-fetched idea: The U.S. Federal Aviation Administration already has a registry for drones.

— Stacey Higginbotham, tech journalist

## EXAMPLES

Fleets of robots were deployed worldwide in 2020. They autonomously sanitized hospital rooms, monitored patients remotely, 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. In Austin, Texas, robots developed by Diligent Robotics retrieved supplies for hospital rooms, which freed staff to spend more time with their patients.

## DISRUPTIVE IMPACT

Do robots need worker rights, too? Researchers raise this question now, especially as robots are predicted to take on more meaningful roles within the workplace and in society. The European Union is already discussing whether there ought to be a special legal status of "electronic persons" to protect sophisticated robots.

## EMERGING PLAYERS

- Diligent Robotics
- UBTech Robotics
- Sanbot
- Zipline
- Starship Technologies
- JD.com
- ZoraBots
- UVD Robots



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# Expert Insight

## The Next Generation of Robots Must Be Adaptable, Customizable and Trainable

**Dr. Henny Admoni**

A. Nico Habermann Assistant Professor, Human-Computer Interaction Institute, Carnegie Mellon University

With COVID-19 locking us all at home, robots should have had their moment in 2020, taking over basic tasks that keep society functioning.

We did see some examples of robots disinfecting public spaces, taking temperatures, and enabling telepresence for tele-health. However most of these robots were limited to simple, pre-scripted routines or required teleoperation by a human.

This underscores the challenge facing robots today: Deploying robots in the chaos of hospitals or grocery stores is much more complex than deploying them in the relatively consistent and controllable environment of factories and warehouses. As robotics moves forward, the field must grapple with dynamicism at every part of the robot's sense-plan-act loop.

One way to deal with dynamic or surprising environments is to be adaptable, and robot learning thus continues to be a perennial theme. The field has gotten pretty good at making robots that perform pre-scripted tasks, and now the big challenge is creating robots that are adaptable, customizable, and trainable.

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> Robot learning will likely continue to be a hot topic in academic programs, research, and industry for several years.

Deep learning (DL) continues to be a dominant force in this area, especially in perception and natural language generation. However, people are also finding the limits of DL systems—such as their reliance on very large data sets and their brittleness to novel inputs. Human-in-the-loop learning (in which a person curates input or provides feedback on a robot's performance) and active learning (in which a robot seeks out the most relevant new information) are both promising approaches. Robot learning will likely continue to be a hot topic in academic programs, research, and industry for several years.

If the 2010s was the decade for dreams about autonomous vehicles, the 2020s are the decade in which we wake up and realize it's not as easy as we thought. (By the way, I'm not picking on AVs; this is a recurring trend in robotics.)

The end of 2020 saw big news with Uber selling off its autonomous driving unit to Aurora Innovation, a startup with deep robotics expertise. Many of the bold promises about autonomous vehicles from the last few years have not panned out, and the industry seems to be settling down now to solve the very real, very hard problems of perception, prediction, controls, and human-robot interaction. I'm confident we'll get there, but, as with much of robotics and AI, it's more complicated than it initially seems.

Of course, it's impossible to talk about robotics (and its close cousin AI) without mentioning robot ethics. The past year has seen increased social consciousness along a number of dimensions, not least of which is the societal impact of automated systems. In late 2020, Google fired researcher Timnit Gebru, launching a national conversation around accountability and ethics in AI. Even before that, though, we saw major AI failures in vaccine distribution, education, and policing. One heartening trend is an increased awareness and interest in AI ethics. For example, universities are starting to offer more tech ethics courses and students are increasingly asking for ethics to be included in their technical education.

**

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# Logistics & Supply Chain

4TH YEAR ON THE LIST

# Capturing IIoT Metadata

Sensors, switches, and connected machines generate lots of data.

## KEY INSIGHT

**The industrial internet of things ( IIoT) refers to all of the hardware that's collecting, sharing, and using data within industrial settings. Some of what's being collected is metadata, which describes the data that's being generated.**

## EXAMPLES

In an industrial setting, sensors, switches, and connected devices generate a tremendous amount of data. That data can be mined, refined, and analyzed for cost savings, greater efficiencies, and even new product development. For example, Palo Alto, California–based Maana extracts metadata to optimize a company's processes by revealing previously unknown relationships. Austin, Texas–based SparkCognition uses metadata for predictive maintenance applications in energy, gas, and utilities.

## DISRUPTIVE IMPACT

There is no unified approach for how to handle metadata in manufacturing and other IIoT settings—and at the moment, not all systems and devices are interoperable. The metadata itself could help solve that problem, by identifying communication protocols that would facilitate the exchange of data throughout a network. Metadata will make it easier for businesses to organize the data generated from all of their connected machinery within the IIoT. Advances in artificial intelligence will offer deeper levels of insight into process automation.

## EMERGING PLAYERS

- Maana
- Plataine
- Augury
- ThetaRay
- SparkCognition



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2ND YEAR ON THE LIST

# Automating the Supply Chain

Berkshire Grey raised $263 million in new funding last year.

## KEY INSIGHT

**Mobile automation in the supply chain is a quickly maturing market. While this means greater efficiencies and cost savings for businesses, it also portends job losses for workers who operate warehouse equipment.**

## EXAMPLES

Autonomous mobile robots (AMRs) and autonomous guided vehicles (AGVs) will become more commonplace, which will bring cost savings and efficiencies for businesses. A new class of autonomous robots and vehicles running on AI-powered logistics systems is coming. In a warehouse setting, autonomous mobile robots assign global tasks, set paths, and optimize tasks like picking. Berkshire Grey is an AI-powered automated system that picks, packs, sorts, and transports products autonomously to fulfillment centers, resulting in a 75% reduction in direct human labor.

## DISRUPTIVE IMPACT

The robotics industry will drastically transform the supply chain. Some researchers anticipate that 6 million mobile robots will be shipped within the next decade, shifting every sector of the global economy.

## EMERGING PLAYERS

- Amazon Robotics
- Robotic Industries Association
- Mobile Industrial Robots



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2ND YEAR ON THE LIST

# Sustainability in Supply Chain and Logistics

Sustainability in the supply chain is a primary driving force in business.

## KEY INSIGHT

**Pressure from investors, customers, and governments—in addition to extreme weather events and trade tensions—demands new efforts to build sustainable supply chains.**

## EXAMPLES

The U.N. Global Compact encourages companies to make sustainability a priority from the top of the organization down into supply chains. India, Indonesia, and China have mandated reporting of sustainability practices, and they will begin publishing their findings. Levi Strauss & Co. partnered with the International Finance Corp. to provide lower interest rates for vendors that have sustainability practices in place.

## DISRUPTIVE IMPACT

As buying power shifts from Gen X and Millennials to Gen Z, supply chain sustainability will become more important—younger consumers repeatedly say they prefer brands that support environmental causes. Investors are taking note: In an Oxford University Saïd Business School study of 70 senior executives at 43 global institutional investing firms, including the world's three biggest asset managers (BlackRock, Vanguard, and State Street), sustainability was a key priority for 2021 and beyond.

## EMERGING PLAYERS

- Sustainability Accounting Standards Board
- Global Reporting Initiative
- U.N. Sustainable Development Goals



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2ND YEAR ON THE LIST

# Rethinking the Cold Chain

Many COVID-19 vaccines require a stable cold chain.

## KEY INSIGHT

**Cold chains are temperature-controlled supply chains—critical for goods such as medications, produce, and frozen foods.**

## EXAMPLES

Last year the cold chain was in the national spotlight, because the most promising COVID-19 vaccines from Pfizer-BioNTech and Moderna required an ultracold transportation system. If the temperature fluctuates or the cold storage fails, it could render doses ineffective. The cold chain is how your local grocery store can sell sushi made from raw tuna and salmon farmed halfway around the world. The reason we can enjoy ice cream in the heat of the summer is the cold chain: a complicated system of storing and transporting food and medicine in exactly the right temperature range during the trek from farm to factory to store. But in some areas of the world, the cold chain has contributed to climate change.

## DISRUPTIVE IMPACT

We put an enormous amount of trust in the cold chain to protect the food and medicines we ingest. Companies are beginning to look at new sustainability opportunities to improve the cold chain. One area of interest is artificial intelligence in the cloud, which can help monitor temperatures and can also optimize travel routes. New packaging materials insulate food and medicine, keeping both at low temperatures without having to refrigerate entire trucks. Climate change could result in new regulations that limit how the cold chain works, but new kinds of intelligent packaging and automated transportation systems mean new business opportunities.

## EMERGING PLAYERS

- QCMedchain
- StaTwig
- Smashtag Chill
- Solar Freeze
- NelumBox



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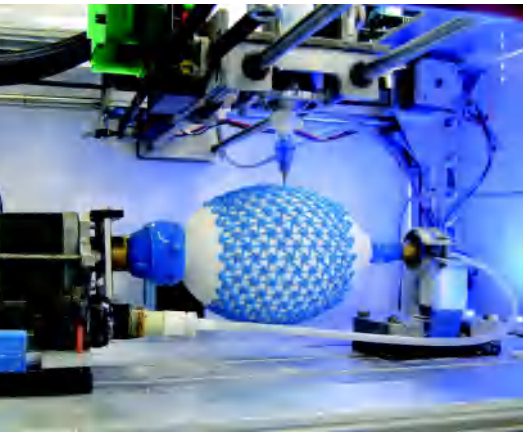
10TH YEAR ON THE LIST

# Additive Manufacturing



A team at U.K.'s Nottingham Trent University are printing artificial muscles.

## KEY INSIGHT

**Additive manufacturing is a process by which materials are deposited layer by layer as objects are printed.**

## EXAMPLES

3D additive manufacturing has moved from the fringe to the mainstream, offering new opportunities in medical and biosciences, manufacturing, and art. LaserFactory, a project from MIT's Computer Science and Artificial Intelligence Lab, uses silver conductive ink to attach circuits together and print circuit boards. Soon, "one size fits all" will take on a whole new meaning. Chinese researchers successfully printed ceramics capable of transforming over time in response to stimuli such as heat and light. It's a process known as 4D printing, and the practical applications are boundless. Imagine a heat shield that suddenly materializes during a fire, or a garden that plants itself when the ground has warmed to precisely the ideal temperature for each seed.

## DISRUPTIVE IMPACT

If you're thinking of the "Star Trek" replicator, you're not far off. Researchers are working toward scanning and producing objects in seconds—over time, this technology will be used in surgical centers to rapidly print replacement valves and joints using your own biomatter as models. We don't yet have international product liability and intellectual property standards, norms, and regulations that govern additive manufacturing and printing. A regulatory framework built to protect designers, patents, corporations, and individuals is likely on the horizon.

## EMERGING PLAYERS

- Autodesk
- Formlabs
- Apis Cor

> Could a brick ever behave like a human cell and evolve, replicate [and] assemble organically with others? Could the objects we now build out of concrete and steel ever be as adaptable, intelligent, and multifunctional as those grown from the earth?

— Paola Antonelli, Museum of Modern Art curator and director of MoMA R&D



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# Drones

10TH YEAR ON THE LIST

# Drones

The COVID-19 pandemic accelerated the adoption of drones.

KEY INSIGHT

**Drones have seen unprecedented market growth and rapid adoption across various industries, thanks to lower costs, easier manufacturing, and their effectiveness in a wide range of use cases.**

EXAMPLES

Companies now use drones for mapping and inspections in agriculture, mining, and construction. Drones inspect dangerous and hard-to-reach places such as chemical weapons plants and erupting volcanoes. The emergence of COVID-19 and racial injustice protests accelerated the already-fast adoption of drone technology. Last year, UPS, CVS, and drone tech company Matternet launched a drone delivery pilot program that allowed Florida residents to shelter in place and receive medical deliveries including documents and blood samples. Controversially, government and citizen drones also tracked protesters and police during widespread marches for social justice, and monitored social distancing amid the pandemic in places including New York, Paris, Mumbai, and China.



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# Drones continued

Agricultural drones can manage crop health from the air.

## DISRUPTIVE IMPACT

The use of drones allows us to work outside the limitations of the human body in a very cost-effective way. We'll likely see a wave of mergers and acquisitions among flight service providers, hardware startups, drone and aircraft manufacturers, asset and flight path management software makers, and data processing platforms. The growing sector may give rise to a new "drones-as-a-service" business model akin to the car and scooter sharing industry, delivering access to drones without the intervention of specially trained experts. We'll also see more government uses, including identifying terrorists and monitoring immigration. In 2017, U.S. Rep. Will Hurd (R-Texas) proposed the Secure Miles with All Resources and Technology (SMART) Act, which would employ a constellation of AI-powered cameras, biometric recognition systems, airborne unmanned vehicles, lidar, and mobile phone monitoring systems, to create a "smart wall" that conducts detailed surveillance, primarily for use at the Texas-Mexico border. The bill stalled in committee, but in the wake of recent public unrest, there's renewed interest—and now, better technology—to make the proposal a reality.

## EMERGING PLAYERS

- Zipline
- Anduril
- Terra Drone
- Hemav
- Matternet



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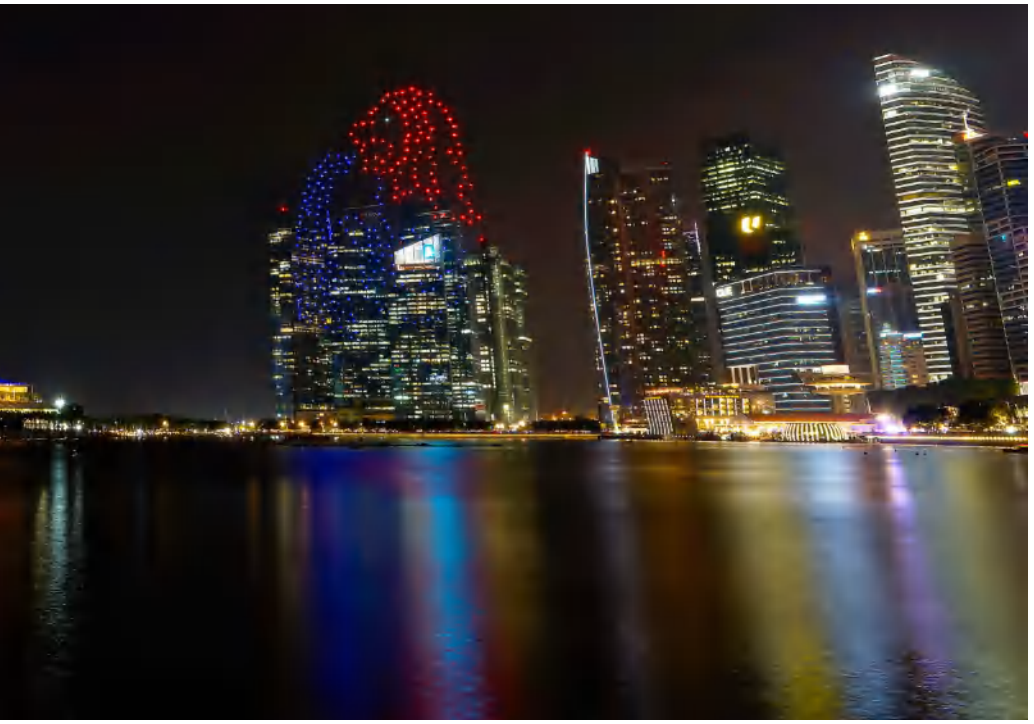
5TH YEAR ON THE LIST

# Drone Swarms



300 unmanned drones performed aerial formations and light shows during the rehearsal for Singapore National Day Parade in 2017.

KEY INSIGHT

**Drone swarms, or fleets of networked drones capable of coordinated operations and communication, are being developed for military operations, surveillance, and other complex functions without human interaction. In a drone swarm, the collective functionality of the overall network becomes more important than each individual drone, and the group of drones can "learn" and adapt synergistically.**

EXAMPLES

The U.S. Army is developing a Cluster UAS Smart Munition for Missile Deployment that would allow a swarm of small drones to fan out and destroy vehicles with "explosively formed penetrators," or EFPs. The U.S. Navy Office of Naval Research intends to launch a swarm of Coyote drones, made by U.S. military contractor Raytheon, for intelligence, reconnaissance, and potentially weaponry. Turkey has deployed Kargu tactical kamikaze drones on the Syrian border via remote pilots. In October, China conducted a test launch of 48 "suicide" drones from a truck and helicopter. This follows a number of other larger swarm-drone experiments by the country in 2017. The U.S. Army plans to build an autonomous charging system that swarm drones could fly to for charging before redeployment. The Army is also working on a giant recharging drone called the Joint Tactical Aerial Resupply Vehicle, which is also intended to serve swarms.

Civilian applications include dazzling light shows and dynamic aerial artwork. Disney and Intel are creating a new type of light show that uses 300 drones with multicolored lights that fly in unison at Disney World.



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# Drones Swarms continued

Drone swarms fan out to automatically amd work as a team to accomplish goals.

## DISRUPTIVE IMPACT

Swarms of drones would allow a single delivery truck to service a full neighborhood or multiple drones to work together in the manner of a school of fish. Ideally, future swarms will use what Nora Ayanian, a roboticist at University of Southern California, calls "leveraging diversity in the control policy," in which each drone is programmed slightly differently so that the one best suited to the task teaches the rest of the swarm how to act. This could make drones more robust in unstructured and uncertain environments, such as in disaster response, environmental monitoring, and military applications.

## EMERGING PLAYERS

- U.S. Navy Office of Naval Research
- U.K. Defence Science and Technology Laboratory
- China Electronics Technology Group



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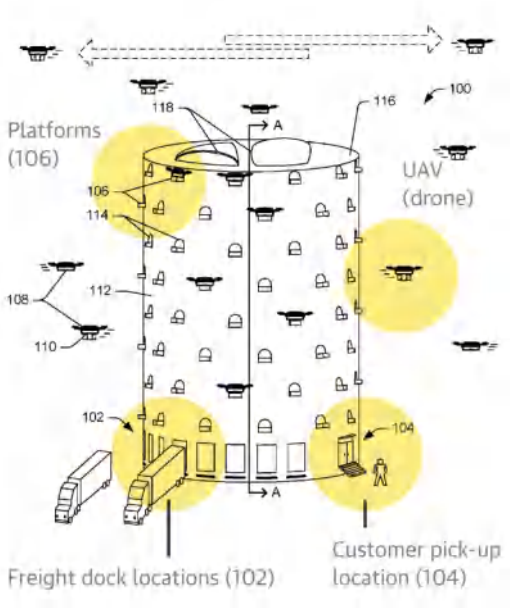
2ND YEAR ON THE LIST

# Drone Fleets




Amazon's patent for a multilevel urban hive.

## KEY INSIGHT

**Fleets of drones operating as air carriers will begin making package deliveries soon.**

## EXAMPLES

The pandemic accelerated drone-delivery certification approvals, as many consumers avoided brick-and-mortar stores. Amazon received U.S. Federal Aviation Administration clearance last year to begin making commercial deliveries under a trial program. Amazon joined UPS and Google as companies certified to make autonomous deliveries. Google's Wing, partnering with Walgreens and FedEx, began its tests last year. UPS now flies medical supplies between buildings on a Raleigh, N.C., hospital campus.

## DISRUPTIVE IMPACT

Amazon has also filed patents for interesting drone-fleet logistics, including a gigantic beehive-like structure, where drones would dock and receive packages, and a laundry chute system attached to houses where packages would drop safely and tumble down to customers.

## EMERGING PLAYERS

- Amazon
- Google's Wing
- UPS
- FedEx
- Walgreens
- CVS



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3RD YEAR ON THE LIST

# Cognitive Active Safety Features

Increasingly advanced safety features are laying the foundation for autonomous vehicles.

## KEY INSIGHT

**Car manufacturers, seeking to meet consumer preferences, are quickly adopting proactive safety functions that also provide the building blocks for full autonomous driving.**

## EXAMPLES

Netradyne makes AI-powered dash cameras that monitor real-time road conditions to reduce accidents. Companies can use the technology inside fleet vehicles to monitor driving behavior and teach commercial drivers how to be safer and more efficient drivers. Comma.ai created Openpilot, an open-source software driver assistance system that uses a $1,200 camera and development kit that allows people to transform their cars so they steer, accelerate and brake automatically, as with Tesla's Autopilot. Comma.ai works with a large variety of car models and manufacturers via a customized Android cell phone mounted to the windshield and connected to the vehicle's existing adaptive cruise control hardware.

## DISRUPTIVE IMPACT

Vehicle manufacturers will continue to implement and tout active safety features to attract safety-minded consumers, with software representing the next wave of advances. Car manufacturer development cycles, historically occurring over a 10 year span, will accelerate as platforms become increasingly software-driven.

## EMERGING PLAYERS

- Netradyne
- Driveri
- Comma.ai
- Tesla



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3RD YEAR ON THE LIST

# Autonomous Last Mile Delivery

Starship Technologies uses robots to deliver food and drinks to George Mason University students.

## KEY INSIGHT

**Autonomous delivery is becoming more common, driven in part by an increased desire for contactless interactions brought about by the pandemic. Delivery is an ideal testing and development ground for autonomous vehicles, as the hurdles for safely transporting food are lower than those for safely transporting humans.**

## EXAMPLES

Nuro, a startup founded by former Google engineers, is developing autonomous vehicles for last-mile deliveries, including take-out, groceries, laundry, and packages. JD.com has autonomously delivered more than 13,000 packages, traveling 6,900 kilometers in lockdown environments. Cenntro Automotive Group's CityPorter electric vehicle will soon make urban deliveries, while General Motors launched a new last-mile delivery business called BrightDrop.

## DISRUPTIVE IMPACT

A study from the World Economic Forum found that rising demand in e-commerce will lead to a 36% increase in delivery vehicles in the largest 100 global cities by 2030, and last-mile delivery will spike 78%. The first widely deployed autonomous vehicles likely won't be transporting humans but rather familiar goods—like pizza. These sorts of autonomous deliveries will continue to gain momentum as a reliable, data-rich, and cost-effective solution for last-mile transportation with the potential to improve customer experiences. These relatively low-stakes deliveries will socialize autonomous technology in everyday society, easing the transition to autonomous vehicle systems for transporting people.

## EMERGING PLAYERS

- Nuro
- Refraction AI
- Cenntro Automotive Group
- Arrival
- Rivian



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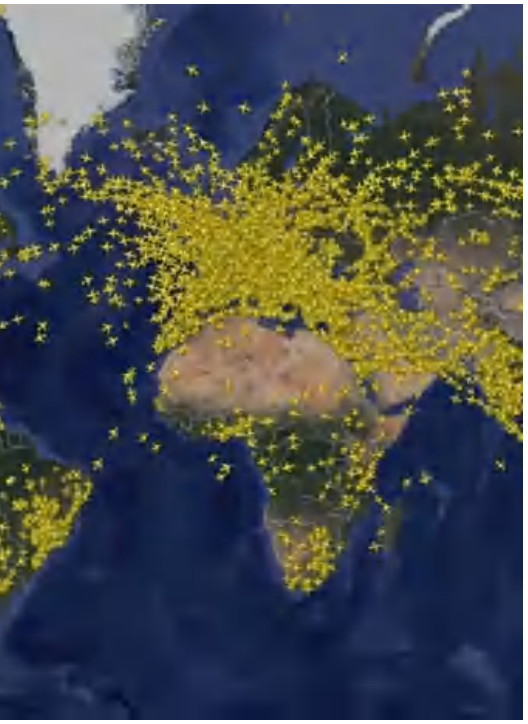
5TH YEAR ON THE LIST

# Air Lanes



**Proactive planning can help avoid an aerial overload.**
Image credit: Flightradar24.

## KEY INSIGHT

**The proliferation of drones will lead to more aviation guidelines, including "air lanes" that will guide low-flying aircraft, both piloted and autonomous. Where and when these new aircraft can operate will significantly impact the built and natural environment, and managing the number of flying drones will be important to ensure safety and noise pollution.**

## EXAMPLES

The U.S. Federal Aviation Administration has updated its Part 135 certification process for package deliveries by drone and is creating new regulation for air safety and industry guidelines. UPS Flight Forward was the first to receive a Standard Part 135 air carrier certificate to operate a drone aircraft in 2019. The FAA is now working with industry as well as state, local, and tribal governments to inform future rules and regulations.

The FAA's new BEYOND program will develop and scale drone delivery operations, establishing rules for infrastructure inspection and public operations. The program will also gather data and community feedback on the social and economic benefits of drones. Vodafone and Ericsson will work together to prove how safe flight path corridors can be created within existing cellular network coverage. Using network traffic data ensures that autonomous drones avoid areas of poor network coverage to guarantee connectivity from departure to destination.

## DISRUPTIVE IMPACT

Regulators have an opportunity to preempt congestion, ensure safety, manage community perception, ensure privacy and learn from road and air travel if they proactively create aerial infrastructure along with key stakeholders. Cities and states will then need to develop regulation to ensure interoperability of drone lanes.

## EMERGING PLAYERS

- U.S. Federal Aviation Administration
- International Civil Aviation Organization
- European Union Aviation Safety Agency
- Civil Aviation Administration of China
- South African Civil Aviation Authority
- Civil Aviation Authority of Singapore



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4TH YEAR ON THE LIST

# Flying Taxis

General Motors debuted its concept eVTOL in 2021.

## KEY INSIGHT

**Compact, unmanned electric aircraft have moved beyond the concept stage, and now a flurry of prototype tests at companies worldwide could open the door for autonomous air travel services to take individuals and small groups short distances.**

## EXAMPLES

In 2021, Cadillac introduced a vertical take-off and landing (eVTOL) personal air taxi. It's General Motors' first foray into the increasingly crowded aerial mobility space. Hyundai, Aston Martin, and other carmakers announced plans to build their own eVTOL aircraft. But there have been setbacks: A fire inside a hangar destroyed a prototype by Germany-based Lilium; Boeing's Aurora Flight Sciences prototype crashed; and Kitty Hawk's one-person vehicle, Flyer, suffered fires involving batteries, electric motors, and wiring.

## DISRUPTIVE IMPACT

Most designs use electric engines that allow for vertical landing and takeoff in urban spaces, enable short- to medium-distance trips, and rely on both piloted and autonomous formats. NASA Ames Research Center and the U.S. Federal Aviation Administration are currently working to create regulations for safety and air traffic control. The result could be hundreds of thousands of delivery drones and air taxis flying in urban and suburban airspace, opening up a new medium of travel for the mainstream passenger and impacting transit design, congestion, and travel times. The high rate of crashes in the helicopter travel industry, including the high-profile fatal crash of Kobe and Gianna Bryant and seven other people in 2020, highlights the need for increased safety in this burgeoning area.

## EMERGING PLAYERS

- European Organisation for the Safety of Air Navigation
- New Zealand government
- EHang



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4TH YEAR ON THE LIST

# Follow-Me Autonomously

Follow-me functionality allows drone operators to capture the moment without worrying about piloting.

## KEY INSIGHT

**"Follow-me" functionality, whereby a drone is able to detect and pursue a moving subject, has burst onto the scene in personal drones for photography and videography, but it has potential applications in a range of settings and situations.**

## EXAMPLES

Many photo- and video-enabled consumer drones available today have "follow-me" and crash-avoidance functionality, enabling semi-autonomous flight, where a subject is kept in the frame of the camera without the need for a designated pilot. This is ideal for capturing solo activities like skiing, surfing, and dance. Most of these drones rely on GPS transmitter technology or recognition software, such as DJI ActiveTrack.

## DISRUPTIVE IMPACT

The ability to automatically avoid crashes and reroute around obstacles greatly increases a drone's safety and versatility. Autonomous conflict avoidance and follow-me functionality reduce stress and sensory demand on the remote pilot, making indoor flight easier and expanding the range of circumstances in which drones can be safely operated.

## EMERGING PLAYERS

- DJI
- Skydio
- Yuneec



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3RD YEAR ON THE LIST

# Inspection Drones

Drones can inspect infrastructure in places that are too dangerous for humans.

## KEY INSIGHT

**As natural disasters and extreme weather events become more common, drones will help with the rapid inspection and interpretation of critical infrastructure.**

## EXAMPLES

Drone inspections are being performed in almost every industry that requires visual inspections, in the aftermath of a weather event or as part of routine maintenance. Drones can capture visual data more safely than humans can—and AI systems process those data in real time. Carnegie Mellon University researchers are developing an AI system that will review amateur drone footage of damage from 2020's Hurricane Laura so that it can perform rapid damage assessments in the future. The system would automatically identify buildings and offer preliminary damage assessments, increasing situational awareness and significantly reducing cost and human labor.

## DISRUPTIVE IMPACT

Increasingly frequent extreme weather events will further strain infrastructure. As civil aviation authorities grant new certifications to allow flights beyond the visual line of sight, drones will gain access to remote gas pipelines, power lines, and other areas that are often only reachable by dangerous backroads.

## EMERGING PLAYERS

- Carnegie Mellon University
- Neurala
- Optelos
- PowerVision Robots



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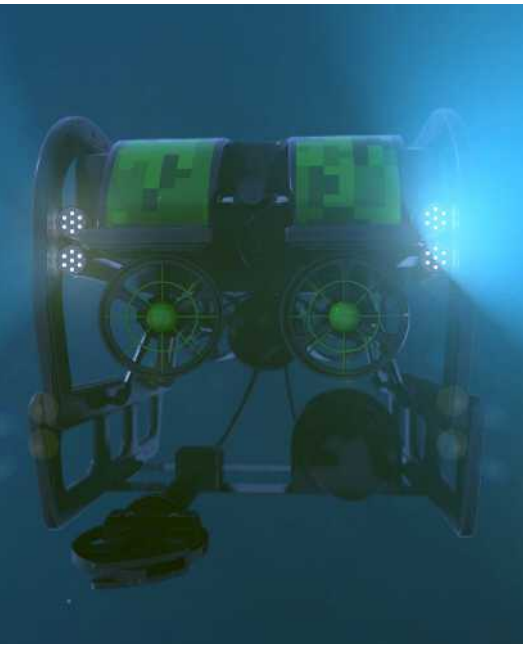
4TH YEAR ON THE LIST

# Autonomous Underwater Vehicles



Autonomous vehicles could significantly help to maintain and inspect underwater structures.

## 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 better batteries, low-light high-definition cameras, and lighter control boxes and sensors.**

## EXAMPLES

The U.S. Navy first developed underwater drones, and such devices were used to discover the wreck of the Titanic in 1985. Modern drones are far more advanced. Today's autonomous underwater vehicles are used to disable mines; to explore for oil and gas drilling; to inspect nets; to feed and stock fisheries; and to reduce costs for monitoring, building, and maintaining underwater assets. General Dynamics' Bluefin-21 drone is known for its 2014 search for the wreckage from Malaysia Airlines Flight 370. Boeing's Echo Voyager is the largest autonomous underwater vehicle, weighing 100,000 pounds, and it can also go the deepest. Boeing and Huntington Ingalls Industries are now developing the Orca drone submarine, designed for military combat, surveillance, and minesweeping. Lockheed Martin's Marlin can create 3D models of its surrounding environment in real time. The navies of France, Japan, Russia, and China, meanwhile, are developing their own underwater technologies. Underwater drones have even become popular among consumer hobbyists and can be purchased online for $500 to $3,000.

## DISRUPTIVE IMPACT

Underwater drones are changing the business dynamics of marine construction, potentially increasing underwater land usage. The potential of improved underwater surface mapping could also cut the costs of laying the transatlantic cables that serve as the backbone of the internet, enabling increased competition and connectivity. Military autonomous underwater vehicles could be used in both offensive and defensive capacities including intelligence, network infrastructure, port security, and more.

## EMERGING PLAYERS

- Blueye Robotics
- Geneinno
- Youcan Robot
- Notilo Plus



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# Transportation

1ST YEAR ON THE LIST

# Vehicular Biospheres

Cars are being used as mobile "quarantine" zones.

## KEY INSIGHT

**Vehicles are evolving into controlled mobile biospheres that allow people to move through the world and spend extended periods in their cars without subjecting themselves to the elements and contagions.**

## EXAMPLES

In its 2015 Model X SUV, Tesla designed an air filtration system called Bioweapon Defense Mode that's allegedly capable of protecting passengers from a military-grade biological attack. The system uses a HEPA filter that can remove particles as small as 0.3 micrometers, roughly the width of a single strand of spider silk. Geely Group says it will spend $53 million to develop cars that purify the air of the cabin and filter out viruses. These sorts of features arrive as vehicular activities like drive-by parties and parades become increasingly common as distanced options for socializing and attending events amid the pandemic, along with an uptick in curbside or in-store pickups for online purchases. The world's largest drive-through animated light show—in Marietta, Georgia, for the 2020 holiday season—extended 1 mile in length and took 30 minutes to traverse.

## DISRUPTIVE IMPACT

The pandemic has made people more sensitive to potential environmental hazards. Many limit their travel source to only their private cars in order to limit exposure. Vehicles as extended personal biospheres or exosuits could necessitate the expansion of dense urban environments and prompt designers to build experiences with the assumption that everyone will participate from within their own personal biosphere.

## EMERGING PLAYERS

- Tesla
- Illumination
- Geely Group



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## Intra-biosphere and intra-pod mobility

### Far-future pessimistic scenario

Car customization shops begin adding options for virus safe air-conditioning systems in addition to their existing armor plating and explosive device countermeasures to a-la-carte modifications for the ultra-rich. The option becomes so popular that car manufacturers take notice, creating car-based biosphere isolation specifications for the entire industry to follow. As a result, cars come with biosphere certifications that allow occupants to prove they did not encounter any contagions, so they can speed through any contagion testing or quarantine restrictions.

# Scenarios



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3RD YEAR ON THE LIST

# Battery-Supported Transportation

Transitioning to grid power from fossil fuels will test energy delivery infrastructure.

## KEY INSIGHT

**The rise of battery-supported transportation will change how we power vehicles, transforming an infrastructure that has historically sourced energy from gasoline to one that delivers it via the electrical grid.**

## EXAMPLES

Battery-powered transportation now extends beyond cars, trucks, and buses to motorized bicycles, hoverboards, skateboards, and scooters. The battery-powered transportation movement will drive new business models and gradually cut demand for fossil fuel-powered transport. California will phase out the sale of gasoline-powered cars by 2035, making a robust and reliable electrical grid even more critically important in the state. Risks are highlighted by the regular rolling power outages during California's wildfire season—or Texas's widespread blackout during a winter storm in early 2021—and are underscored by Tesla's new in-car warnings to drivers about upcoming power outages nearby.

## 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 to provide charging infrastructure along travel routes will shift traffic patterns and create new networked economies—similar to how the interstate highway system created an economic boom for certain towns and hurt those cities that were bypassed.

## EMERGING PLAYERS

- Tesla
- ChargePoint
- EVgo
- Blink Charging



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## Distributed Grid

**Mid-future optimistic scenario**

Charging infrastructure becomes fully standardized and interoperable. Charging stations become commonplace and are readily available publicly and privately on highways, rural roads, and urban centers. Fast and slow charging is readily available in homes and at charging stations. The electrical infrastructure adapts and offers dynamic energy consumption across the entire system, reducing pollution and delivering cleaner energy than its petroleum-based predecessors.

The grid becomes distributed, scalable, and self-routing in a manner that maximizes efficiency and safety. Consumption can be predicted and mapped very accurately, reducing peak load and overcapacity needs. Systems are designed and developed where batteries and devices connected to the grid can receive and return power as needed in an open ecosystem.

## Competing Standards

**Mid-future neutral scenario**

Charging infrastructure develops regional level interoperability with one or two primary standards to which all-electric vehicles can connect. Public charging stations concentrate around interstate highways and urban centers, driven by the adoption of upper-middle-class commuters and commercial trucks. Most of the charging happens at home with residential charge points. Electricity infrastructure has a limited adaptation to the increased demand. Power generation continues with limited decreases in overall pollution. Utilities aggressively incentivize consumers to shift electricity demand across non-peak times by limiting fast charge times and conditions. Blackouts and brownouts become more common and predictable like snowstorm and fire disruptions… inconvenient, but generally accepted.

## VHS vs Betamax, But for Cars

**Mid-future catastrophic scenario**

Energy infrastructure delineates the haves from the have-nots. The charging networks are not interoperable, and we develop dongle hell for cars. Fragmentation persists until there is market saturation and the government steps in, mandating interoperability. Think Apple iPhone forcing people to buy Bluetooth headphones versus Android phones, only this time it is Tesla versus Volkswagen.

Fuel for power plants and electricity generation does not adapt, so the electricity powering our transportation is less efficient and more polluting than the gas-powered cars they are replacing. We become increasingly dependent on the outdated infrastructure that begins to decay at an increasing rate under the new load causing frequent brownouts and blackouts. States and municipalities begin to compete on delivering power, redistributing population centers, furthering divisions of wealth and opportunity.

# Scenarios



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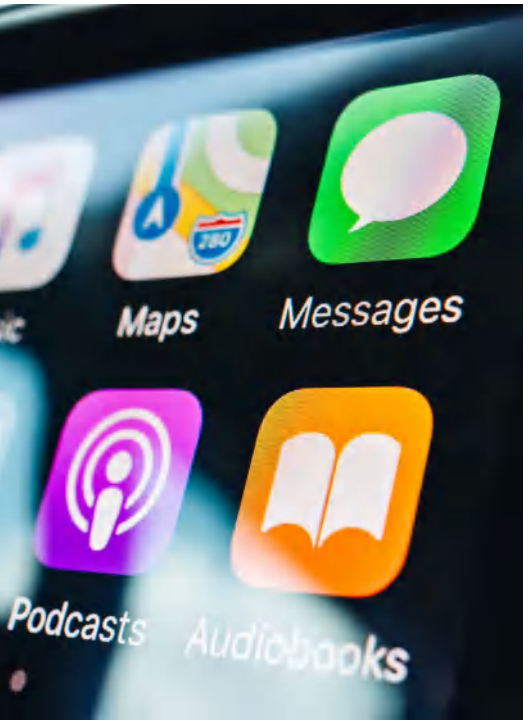
3RD YEAR ON THE LIST

# Car OS




Technology companies are building operating systems for the cockpit.

## KEY INSIGHT

**Platforms are building operating systems for smart cockpits.**

## EXAMPLES

Amazon, Apple, and Google are competing to gain a foothold in the auto entertainment industry as carmakers incorporate smartphones directly into driving interfaces. Amazon's Alexa Custom Assistant was developed for the enterprise: Companies such as Stellantis are using it to develop their smart cockpits. Volvo's Polestar 2 uses the Android Automotive OS custom-built by Google.

## DISRUPTIVE IMPACT

The major platform players increasingly view car ecosystems as prime real estate not only for customer attention but for data collection. As consumers spend more time in their cars without as much need to pay attention to actually driving, carmakers must decide whether to design their own systems and compete with tech titans or to give up ownership of the infotainment dashboard to third parties. The applications available on each car platform will likely determine adoption and ultimately decide the market winners and losers.

## EMERGING PLAYERS

- Tesla
- Google's Android Automotive OS
- Amazon's Alexa Custom Assistant
- Apple's CarPlay



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5TH YEAR ON THE LIST

# Transportation-as-a-Service Business Models

New business models are shifting from ownership to subscriptions and pay-as-you-go.

## KEY INSIGHT

**The business models for transportation are shifting to subscription and pay-per-use structures, as bike, scooter, and car ride-sharing services become more common.**

## EXAMPLES

The business model of ride-sharing services Uber, Lyft, Via, and Gett now extends beyond cars. Citi Bike provides rentals of electric and non-electric bicycles, while Bird, Spin, Skip, eCooltra, and Ioscoot offer scooter rentals. Car rental companies like Hertz, Avis, and Sixt now offer rentals by subscription, by the minute, or by the mile in specific urban centers. Carmakers are also testing new ownership models, such as Audi Select, Access by BMW, Genesis Spectrum, Porsche Drive, and Porsche Host.

## DISRUPTIVE IMPACT

The high upfront investment, maintenance costs, and rapid depreciation associated with traditional car ownership will dissuade potential car owners as they avail themselves of transportation options with subscription models or per-use rates. Consumers will likely demand business models that are personalized and maximize flexibility and cost-efficiency.

## EMERGING PLAYERS

- Gett
- Via Transportation
- Sixt

What year will fleet-owned autonomous cars outnumber family-owned cars in the U.S.?



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3RD YEAR ON THE LIST

# Forced Updates

A driver attempts to diagnose engine problems on his own in the middle of traffic.

## KEY INSIGHT

**In an ideal world, keeping software updated ensures the safest and best experience possible. But in reality updates are often mandatory and sometimes cannot be postponed or avoided, meaning they can unexpectedly take systems offline, force unwanted changes, and expose users to unforeseen bugs and vulnerabilities.**

## EXAMPLES

Forced updates can be either good or bad. When Tesla issued an update to its Model 3 that improved braking distance by a full 19 feet, that was good. When Microsoft's Windows 10 forced an unannounced mandatory restart in the middle of a professional gamer's livestream to 130,000 followers, that was not good. Microsoft has since rethought its policy of forced updates.

## DISRUPTIVE IMPACT

When a provider like Microsoft or Google changes a keyboard shortcut or switches the delete and archive button, frustration often ensues. Now imagine if Tesla reprogrammed which button or pedal sounded your horn, or applied your brakes—the result could be catastrophic. Or say you're in a rush to a critical meeting, but because of a billing hiccup on your car's lease, security software suddenly kicks in that restricts your maximum speed to 65 mph. Automotive platforms will evolve continuously, with new features and functionality added via over-the-air firmware updates. Providers will increasingly navigate the difficult path of introducing new features to keep pace with evolving technologies and improving customer experiences, while ensuring major changes are introduced gradually enough to avoid creating new user-error risks.

## EMERGING PLAYERS

- Tesla
- Amazon
- Google
- Apple
- General Motors
- Microsoft



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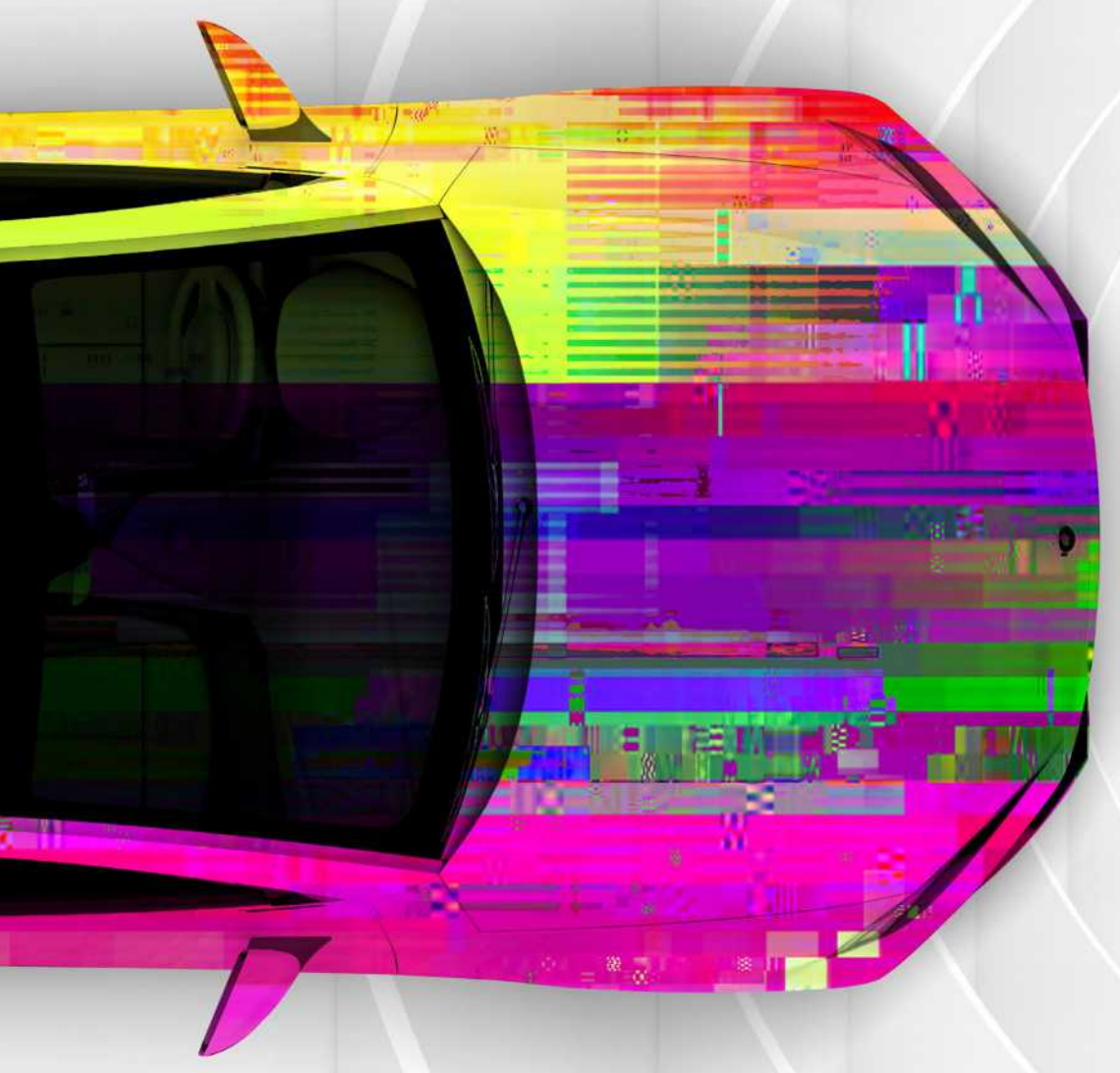

## Experiential Interruptions

**Near-future neutral scenario**

Autonomous vehicles pave the way for experiential transportation. Your car can double as a theater, a cocktail bar, or a library… for an additional fee. When the car is no longer the product you buy, service is essential and content is still king. If you're unwilling to pay a premium, you might be stuck watching a movie you've already seen while also being inundated with deliberate product placement. Pop-up ads block those scenic mixed reality views during long car trips. Augmented OLED windows malfunction and lag, displaying blue screens and spinning wheels, giving new meaning to the term "car crash." Getting from one place to another is a trade-off between the journey and the destination.

Scenarios



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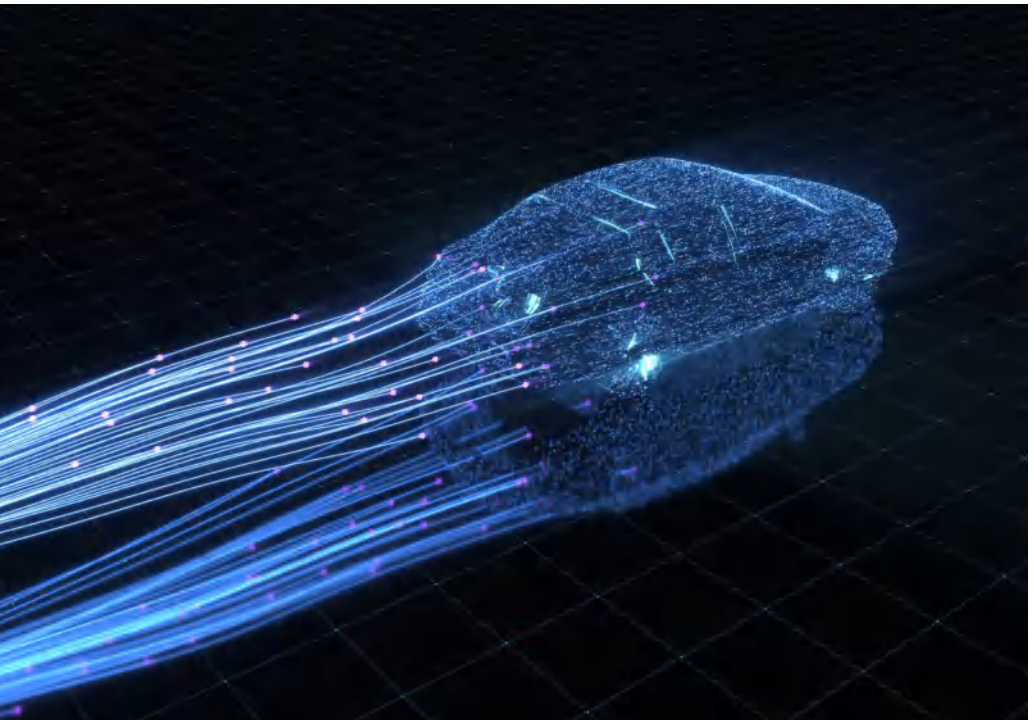
3RD YEAR ON THE LIST

# Exponential Growth in Autonomous Driving Data



Training data is critical for building AIs like those used in autonomous vehicles.

KEY INSIGHT

**The quality of any algorithm has a significant correlation with the size of the dataset on which it is trained. The size of these datasets in autonomous driving is reaching an inflection point as the number of autonomous car users regularly generating real-world driving data approaches critical mass. Beyond this influx of real, raw data, methods of generating synthetic training data are reaching maturity.**

EXAMPLES

Approximately 200,000 Tesla vehicles now navigate the roads using autopilot. With the increase in autonomous miles logged, emerging patterns in the data will help solve some of the problematic edge cases in the algorithms (those that occur rarely or only under extreme conditions). The current algorithms have at times struggled to identify stationary objects, in the worst cases resulting in catastrophic crashes. Shortcuts to training the AI systems are beginning to mature. Helm.ai uses a deep teaching methodology that programs the system to understand base rules like object permanence, effectively giving the AI a head start on learning. Massachusetts Institute of Technology created a digital laboratory to translate real-world situations into simulated scenarios using deepfake technology—allowing AI to train quickly and at lower cost in a virtual environment, but on data based on real-life circumstances. Volvo trains AI on edge cases using a virtual environment based on the Unity gaming engine. Rockstar Games received attention for stopping organizations such as OpenAI from using its "Grand Theft Auto" game as a platform for training self-driving cars.

Synthesized data can help us get to the edge cases faster, meaning more progress per mile analyzed, and making the algorithms safer overall. To put edge cases in context, think of how many miles one would have to drive to come across a pedestrian on stilts crossing paths with a cyclist doing a wheelie in a rainstorm? It sounds highly unlikely, but if the algorithm has never been exposed to such a situation, it might make a fatal error—which is why it's important to expose the algorithm to as many of these atypical cases as possible.



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# Exponential Growth in Autonomous Driving Data continued

As cars with autonomous features become popular, they generate data to help systems improve.

## DISRUPTIVE IMPACT

The company with the most training data should best be able to reduce its vehicles' autonomous-driving error rates, potentially cultivating a powerful brand association with safety—think Volvo in the '80s or Subaru in the 2010s. With the stigma of autonomous driving as an under-regulated and potentially untrustworthy technology, perceived safety performance may be the most important factor for winning market share. For carmakers, however, autonomous algorithms aren't necessarily a "winner take all" market, because the developer with the best system could resell or license its software to other players.

## EMERGING PLAYERS

- Helm.ai
- Oxbotica
- Nvidia



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4TH YEAR ON THE LIST

# Autonomous Vehicle Testing Gets Regulated

Who will give AI its driving license?

## KEY INSIGHT

**New rules will govern how autonomous vehicles can be tested. Current legislation around autonomous cars is in flux and has yet to be set at a national level.**

## EXAMPLES

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. ITU, the specialized United Nations agency for telecom and information communications technology, created a focus group to develop performance standards for autonomous vehicles, including what an "AI driving test" should entail.

## 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.

## EMERGING PLAYERS

- Focus Group on AI for Autonomous and Assisted Driving
- U.S. National Highway Traffic Safety Administration
- National Conference of State Legislators



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3RD YEAR ON THE LIST

# Analog Fallbacks

How do you open a door that is frozen shut—and has no handles?

## KEY INSIGHT

**As more systems and infrastructure transition to digital formats, and more purely digital systems are built, fewer of these systems will rely on analog or manual fail-safes. When these unprotected digital systems fail, it will lead to increasingly catastrophic outcomes. Electrical systems are historically more sensitive and 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

There is hardly a more apt application of the phrase "They don't make 'em like they used to" than the auto industry. As vehicles become more automated, manufacturers must design for the appropriate level of redundancy and for a population of people with limited understanding of how the underlying systems work.

## EMERGING PLAYERS

- Cadillac
- Corvette
- Tesla
- Range Rover



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# Scenarios

## When Humans Attack Cars

**Near-future pessimistic scenario**

Every year, more than 200,000 people die in a car accident. That's about one person every three minutes in the United States. Millions more are hospitalized because of car-related injuries. And now there's a twist: armed with rocks, guns, pocket knives, and in one instance, a PVC pipe, humans have started attacking cars.

The reason: big tech companies must adjust their self-driving technology to real-world communities that aren't interested in being test subjects. Google's Waymo division, which has been testing vans near Phoenix since 2017, has had several run-ins with locals: they've slashed car tires, pelted vehicles with rocks, and tried to run vans off the road. Residents have safety concerns, especially in the wake of a 2018 collision involving a pedestrian and a self-driving Uber car just a few miles away in nearby Tempe. But the real issue here isn't safety. It's that we all struggle to cope with technological change, especially when it disrupts the foundations of everyday life.



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2ND YEAR ON THE LIST

# Urban Planning for Multi-Use Roads

Road design will accommodate more uses than ever before.

## KEY INSIGHT

**As the role of car ownership shifts in society, public roads will transform. Streets and sidewalks are increasingly becoming mixed-use spaces as a greater variety of transportation methods become popular and prevalent. The pandemic-related need for outdoor dining and commerce has accelerated the redistribution of street space away from car travel and parking.**

## EXAMPLES

Strava Metro is using the data from runners and cyclists to help urban planners design safer streets. The National Association of City Transportation Officials released evolving guidelines for street space design and pandemic recovery strategies. They include various street use cases, including protests, voting, outdoor dining, and markets. Slow streets are designed to limit traffic in certain residential areas.

## DISRUPTIVE IMPACT

Intelligent load balancing and redistribution of transportation real estate could significantly increase the throughput of existing transportation infrastructure. Increased quality, quantity, and diversity of traffic data will enable cities to redistribute how much attention and space is designated for car travel and storage versus use by pedestrians, cyclists, and others.

## EMERGING PLAYERS

- Strava Metro
- Open Streets Project
- National Association of City Transportation Officials



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1ST YEAR ON THE LIST

# China's Open Road

China's Byton hopes to rival the world's most prestigious auto manufacturers.

## KEY INSIGHT

**China's ambition to dominate the global car industry is buoyed by its manufacturing sector, work in AI, and vast troves of driving data.**

## EXAMPLES

Although we don't see their vehicles in the West, there are more than 70 Chinese car manufacturers, and together they produce more cars than any other country. For decades, the Chinese government has been paving the way for joint ventures: Many cars in Beijing with foreign badges were actually made by domestic auto manufacturers. An electric vehicle boom is underway, and China's newest cars are full of high-tech gadgetry including wrap-around digital dashboards and seats that swivel so passengers can enjoy a meal together when in self-driving mode.

## DISRUPTIVE IMPACT

China is creating a new mobility ecosystem that includes electric vehicles, apps, communications systems, AI, and data—and it intends to ship its products to the West. Baidu's Apollo is one example of an open-source self-driving system that could become an industry standard. Its partners include Daimler, BMW, and Ford.

## EMERGING PLAYERS

- Apollo Committee
- Baidu
- Volvo
- Ford
- Geely Group
- Dongfeng Motor
- Tencent
- Great Wall Motors



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1ST YEAR ON THE LIST

# New Cityscape Designs

The Line is a linear city proposed in Saudi Arabia.

## KEY INSIGHT

**Autonomous vehicles, collaborative drones and robots, and AI are leading to changes in how cities are designed.**

## EXAMPLES

Saudi Arabia is developing futuristic new megacities. A linear city called The Line will stretch from the Red Sea to the mountains of northwest Saudi Arabia and consolidate urban centers into a 106-mile-long stretch of land. The entire city will be arranged along a multilevel spine, which will include local and high-speed transit, a service layer, and a pedestrian layer. The goal is to preserve the area's wilderness, encourage mobility, and test renewable energies at scale. The Qiddiya giga-project is a $500 billion bet on a megacity contained within a 130 square mile site outside of Riyadh, the KSA's capital. If these projects are successful, they will have advanced technologies and urban ecosystems that rival any major city.

## DISRUPTIVE IMPACT

With climate change accelerating, these projects are an approach to redesigning how we live. 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



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1ST YEAR ON THE LIST

# Decarbonizing Flight

Airbus revealed its zero-emissions plane, one of several hydrogen-powered aircraft projects it has underway.

## KEY INSIGHT

**Hydrogen fuel cells could power commercial aviation.**

## EXAMPLES

Last year, ZeroAvia successfully completed an 8 minute flight that resulted in no carbon emissions. Using a retrofitted Piper M-Class plane, the test proved that hydrogen—which carries little or no carbon footprint—could someday become an alternative to fossil fuels. Airbus has three hydrogen power programs in the works and could start testing commercial flights as early as 2025.

## 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



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5TH YEAR ON THE LIST

# Supersonic Flights

A sonic boom caused by an F-18 Super Hornet.

## KEY INSIGHT

**Several companies are developing technology to bring back commercial supersonic jet travel.**

## EXAMPLES

After years of successful transatlantic flights, the age of supersonic jet travel came to an end in October 2003, when British Airways permanently grounded the Concorde. Driven in part by the enthusiasm and excitement over faster autonomous travel, supersonic jets are being tested once again. Japan Airlines invested $10 million in Colorado-based Boom Supersonic to develop supersonic jets, which will travel at 2.2 times the speed of sound—or about as twice as fast as a standard aircraft. Japan Airlines has already preordered 20 such jets, and Boom unveiled its prototype in October 2020 for test flights in 2021. Aerion Supersonic in Nevada is also developing a carbon-neutral supersonic jet that is expected to take off in 2023.

## DISRUPTIVE IMPACT

Faster travel between locations could stimulate economic development and bring cultures closer together. Reduced sonic boom will enable flights to take off over land, overcoming a significant limiting factor in the routes that the original Concorde could fly. But fuel efficiency and safety concerns may slow progress in getting supersonic air travel to market in the short term.

## EMERGING PLAYERS

- Aerion Supersonic
- Boom Supersonic



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# Scenarios

## The End of Traffic

### Mid-future optimistic scenario

In the next 10 years, companies master vertical takeoff and landing craft that operate similarly to helicopters but they are affordable, easy to pilot and easy to maintain and as cost-efficient as car transportation. Commuters increasingly adopt short distance aerial travel as their regular form of transportation. This redistributes traffic on roadways, which are now dominated only by heavy and long-distance transport, while light transit takes to the air.

## Pilot Shortages

### Mid-future neutral scenario

New aircraft are developed but continue to require highly trained and skilled operators like helicopter pilots. Technological advances for more economical operation, opening up specific commutes and routes, mostly along existing helicopter routes that will handle increased capacity due to lower cost. Island hopping and taking the chopper to the airport will be available to the affluent instead of just the hyper-wealthy. The adoption of regulations and infrastructure modeled after helicopter transport incorporate more significant pilot assistance systems reflecting autonomous vehicle regulations.

## Forgotten Infrastructure

### Mid-future pessimistic scenario

Flying taxis become the method of travel of choice for the hyper affluent, who only travel in the air. Air transit becomes a lightning rod for the global wealth divide, as less is invested in land-based transit infrastructure and public transportation.



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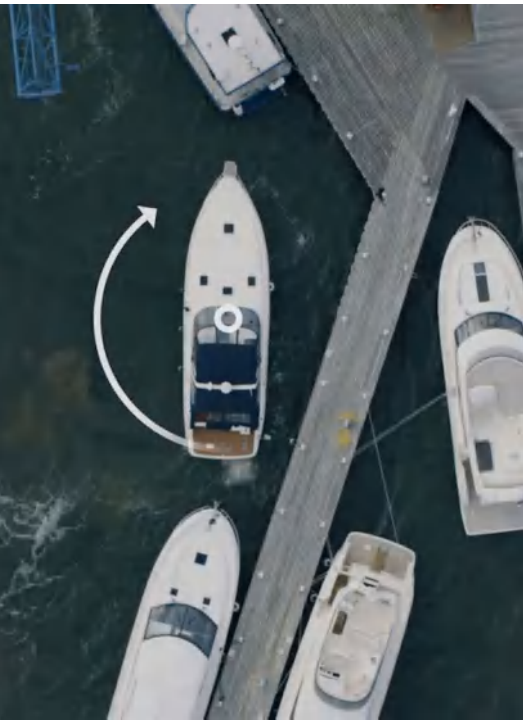
4TH YEAR ON THE LIST

# Autonomous Ships



Volvo Penta launched an autonomous boat docking system.

## KEY INSIGHT

**Efforts are underway to create autonomous, AI-powered ships, and the legal framework is emerging for them to operate safely and officially in international waters.**

## EXAMPLES

IBM and ProMare, a marine research organization, launched a fully autonomous ship called Mayflower, from Plymouth, England, last year. It features an AI captain that gives the vessel the ability to assess its environment and make decisions at sea with no human captain or onboard crew. Volvo's maritime subsidiary Penta launched an autonomous boat docking system—boat captains push a button and it docks without human assistance. Norwegian chemical company Yara International built The Yara Birkeland, an electric container ship supported by radar, lidar, machine learning, computer vision, an automatic mooring system, and a network for cameras. The company planned to transition the vessel from human-crewed operation to remote-crewed operation in 2019, and then to autonomous operation in 2020. The pandemic slowed the timeline, and humans are staying on board for now—which helps with regulatory and insurance complications, too.

## DISRUPTIVE IMPACT

Large autonomous ships could transform shipping by increasing efficiency, reducing costs, and reducing human error. Electric ships that don't require human crews could offer cost savings throughout the shipping supply chain. They could solve labor shortages, increase safety, and reduce environmental harm. The International Maritime Organization is performing a scoping exercise before drafting the legal frameworks for maritime autonomous surface ship travel. In the near to midterm, the goal is to design AI systems that will support human-crewed ships.

## EMERGING PLAYERS

- ProMare
- Penta
- IBM
- Marine AI
- Yara International
- Wärtsilä



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3RD YEAR ON THE LIST

# China's Foreign Infrastructure Investment

## KEY INSIGHT

**The governments and companies that lead international infrastructure projects have powerful influence on setting regional, global, and geopolitical standards. China's multibillion-dollar Belt and Road Initiative is the source of massive investment in infrastructure development, including roads, rail, sea, and air travel. The vast extent of the investment and partnerships with Asian, East African, European, and developing countries has helped make China the preferred financier and producer of transport and power infrastructure on the global geopolitical scene.**

## EXAMPLES

China's Belt and Road Initiative began in 2013 and has primarily focused on investment in infrastructure, education, construction, rail, highway, auto, and the electrical grid. The effort is enormous—roughly 12 times larger than the U.S.'s Marshall Plan, which helped Europe rebuild after World War II. In 2017, the Belt and Road Initiative involved an estimated 68 countries, 65% of the world's population, and 40% of global gross domestic product.

## DISRUPTIVE IMPACT

Critics worry that the debt created by the project will cause an imbalance of leverage in geopolitical relations. Many of the countries involved are developing nations that urgently need the infrastructure, but may have limited ability to handle the debt sustainably. While China is offering a moratorium on debt servicing during 2020, the debts will eventually come due and require potentially long-term global partnerships to address.

## EMERGING PLAYERS

- Asian Infrastructure Investment Bank
- New Development Bank
- National Development and Reform Commission



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# Application

## STRATEGY

Information technology, supply chains, transportation, and network connectivity are becoming more complex, which will require strategists to be more agile in near-term planning. Savvy corporate strategists will consider how this complexity could lead to a broad range of possibilities. Rather than waiting for further developments, organizations should continually identify signals to inform strategic decisions, monitor outcomes, and determine where they can play—and win.

## INNOVATION

Network upgrades, decreased latency, automated transportation, and new delivery options unlock a wide swath of new products, businesses, and opportunities to grow. The next several years will be dynamic, with continual improvements across many sectors. Innovation teams must be prepared to monitor development and anticipate change.

## R & D

R&D leaders are playing a larger role in identifying businesses of the future, with some asked to present their ideas to their executive leadership and boards. Going forward, R&D leaders will need to consider a broader range of trends. For example, in what ways will 5G lead to new business growth in agriculture and finance? An organization's ability to think beyond existing business units will deliver stronger outcomes as the trends described in this volume mature.

## RISK

Trends in networks, transportation, logistics, robotics, and transportation are complex and involve a tech stack that many organizations don't yet have. Chief risk officers should consider developing a strategy to optimize risk to deliver stronger business models—rather than using governance to slow the adoption of emerging technologies and standards.



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# 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 actively developing and testing new ideas related to the trends explored in this volume?

In what ways could our logistics, supply chain, or communications systems be improved?

2

What parts of our business make us vulnerable to disruption in networks, logistics, or transportation? When was the last time we audited the systems that keep those parts of our business safe?

3

Are we adequately planning for the longer term?

What assumptions must hold true for our current strategy to succeed? How will we make needed changes?



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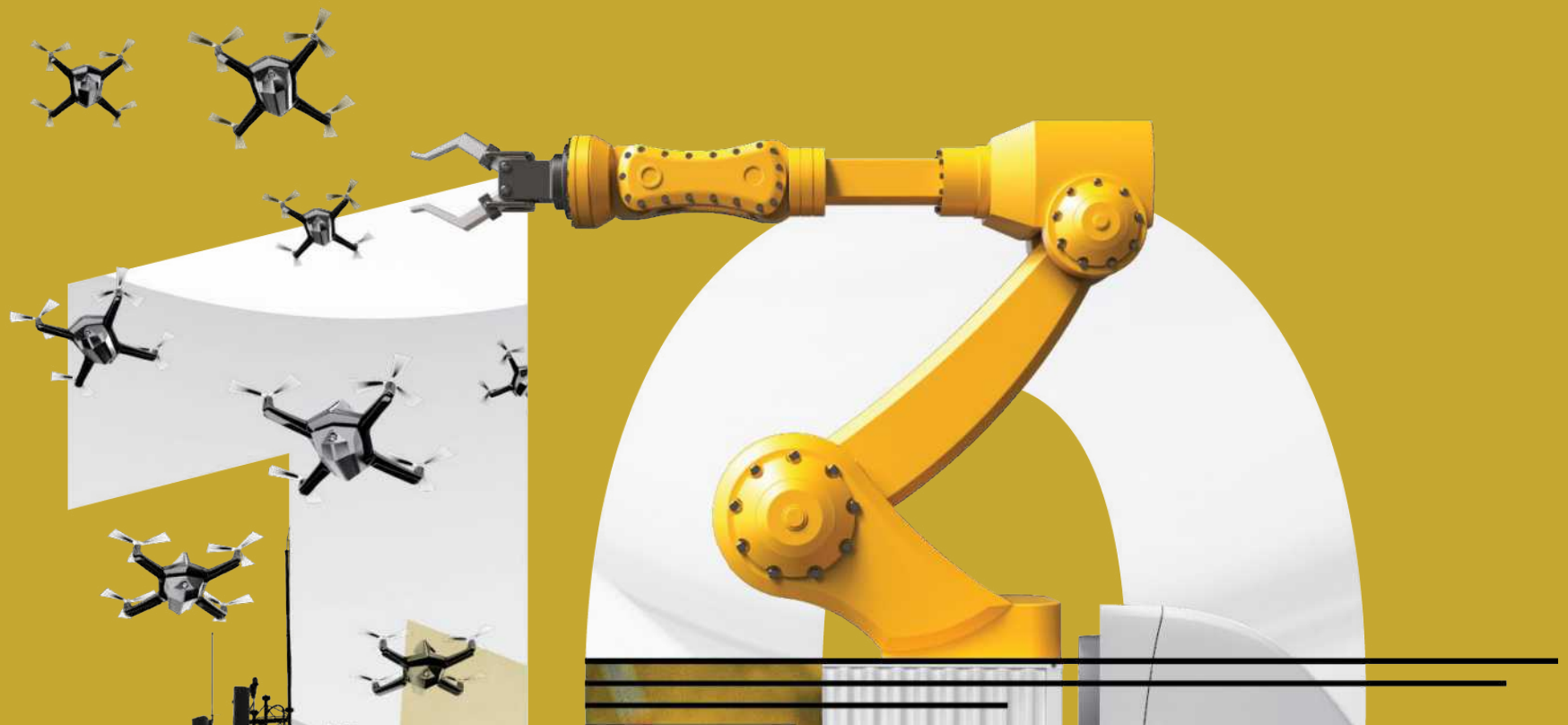

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Volume 11 of 12

14th Annual Edition

# 2021 Tech Trends Report

Strategic trends that will influence business, government, education, media and society in the coming year.

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474 Key Questions
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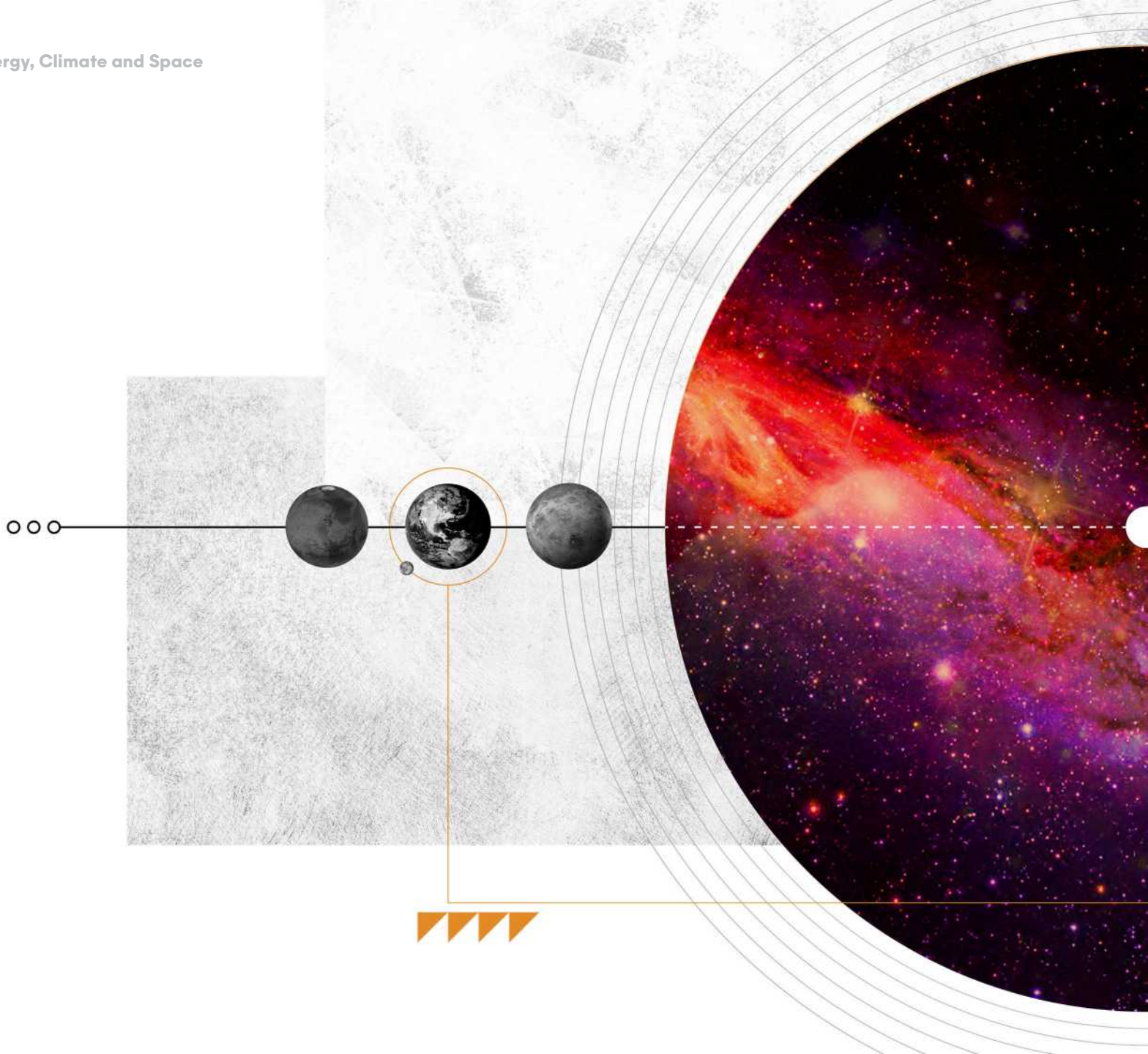

# Energy Climate & Space Summary

- With the new Biden Administration, the U.S. will reverse course on recent energy, climate, and sustainability policy.
- The lasting economic consequences of climate change are dire, which is why so many start-ups are promising to mitigate climate change.
- Several countries will debut green stimulus packages, unlocking new business opportunities.
- Innovative energy research is well underway, ranging from smart grids powered by artificial intelligence to million-mile batteries.
- This is an important year for space missions, including tens of thousands of satellites deployed in megaconstellations promising to beam internet connectivity from space.
- A new space economy is forming, and tensions are arising as China aims to become a major driver of space-related commerce and trade.



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# Energy

2ND YEAR ON THE LIST

# Million-Mile Batteries

Million-mile batteries could revolutionize the electric vehicle market.

## KEY INSIGHT

**As more devices and vehicles rely on battery power, 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. Ultimately the industry strives to produce a battery that could power up to a million miles of drive time before needing replacement.**

## EXAMPLES

Tesla launched its "million mile" project last year to power a vehicle's entire life cycle on a single battery. Contemporary Amperex Technology will make ultra-capacity batteries that last 16 years for Audi, Porsche, and BMW. General Motors is working on a similar battery. Researchers are working to improve battery design, composition, and storage: The U.S. Department of Energy's Pacific Northwest National Laboratory discovered how to make a more efficient and stronger single-crystal, nickel-rich cathode. The University of Münster in Germany found a way for single-use zinc-air batteries to be recharged hundreds of times. And Spanish startup Graphenano built a battery out of graphene that charges a car in eight minutes. Japan's Ritsumeikan University and Panasonic are trying to squeeze the last bits of untapped energy out of lithium-ion batteries, particularly because they don't recycle well.

## DISRUPTIVE IMPACT

Batteries, essential to our everyday lives, will become more important as climate change worsens. Better, longer-lasting batteries not only improve energy usage and efficiency, they allow us to communicate, connect, and continue daily activities during energy disruptions. Researchers at Daimler, Fisker, Jiangxi Ganfeng Lithium, Massachusetts Institute of Technology, Stanford University, and Tokyo Institute of Technology are working on replacing flammable liquids in batteries with solid materials. The result may be safer, cheaper batteries with greater storage and greater drive range for electric vehicles. If successful, the tech could drop electric vehicle charging times from several hours to 10 minutes. By 2027, the lithium-ion battery market could hit $129.3 billion, and the electric vehicle battery market could expand to $133.46 billion.

## EMERGING PLAYERS

- Contemporary Amperex Technology
- Tesla
- General Motors
- Panasonic
- LG Chem
- Aurora
- BYD



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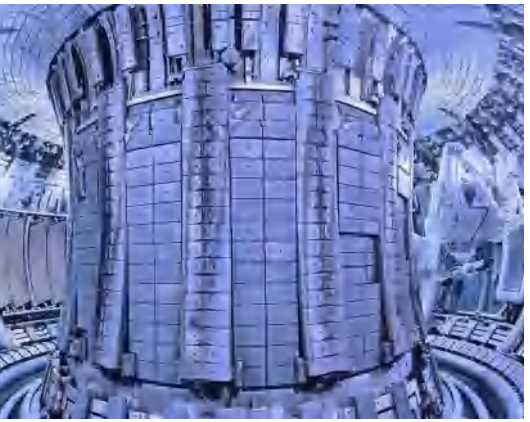
1ST YEAR ON THE LIST

# Fusion Power



Inside a nuclear fusion reactor.

## KEY INSIGHT

**Fusion power plants could produce carbon-free electricity by harnessing the same nuclear process that powers the sun. In the next decade, fusion researchers will discuss and prototype ideas to design a fusion reactor.**

## EXAMPLES

Researchers and government agencies from 35 countries are collaborating to build the largest tokamak, the central component of a magnetic fusion project that will prove the feasibility of fusion as a large-scale and carbon-free source of energy. Construction on the ITER ("the way" in Latin) is already happening in southern France. The project, featuring the first device that can maintain fusion over long periods of time, could lay the groundwork for the commercial production of unlimited, fusion-based electricity. The U.S. National Academies of Sciences, Engineering, and Medicine introduced a road map to fusion power in late 2020, identifying technological gaps and near-term facilities to fill them. It calls for the U.S. Department of Energy to build a prototype in the 2040s to produce our electricity from fusion rather than fossil fuels.

## DISRUPTIVE IMPACT

Fusion research has primarily been funded through basic science initiatives from government agencies (such as the DOE's Office of Science.) But fusion research has gained support from outsiders, and efforts to use a practical, applied approach are growing. This could unlock a new value chain: facilities, advanced lasers, and computer systems that need to be built.

## EMERGING PLAYERS

- DOE's Fusion Energy Sciences program and Federal Fusion Energy Sciences Advisory Committee
- ITER
- SLAC National Accelerator Laboratory



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1ST YEAR ON THE LIST

# Clean Hydrogen

Ørsted launched a pilot for green hydrogen.

## KEY INSIGHT

**Hydrogen is abundant, ubiquitous, and a versatile energy carrier. It can be produced from a wide range of sources and used in many ways across the energy sector. Clean hydrogen could play an important role in transitioning much of the world away from carbon-based energy sources.**

## EXAMPLES

There are different types of hydrogen. For example, hydrogen produced industrially from natural gas results in high carbon emissions; it's known as "gray" hydrogen. But a different process, which captures and stores emissions, results in a cleaner "blue" hydrogen. "Green" hydrogen is generated by renewable energy sources and never results in carbon emissions. Because hydrogen burns at very high temperatures, it is an effective replacement for fossil fuels in industrial applications.

France invests heavily in producing green hydrogen. Out of a 2020 stimulus package worth 100 billion euros, the country dedicated 7.2 billion euros to a project that will create green hydrogen by 2030. The French government has set a target of 10% green hydrogen use in industry for 2022 and 20% to 40% for 2027.

## DISRUPTIVE IMPACT

Right now, clean hydrogen is expensive, and traditional energy sources are simply more affordable, especially when used at scale. But government investments could spur a new clean hydrogen economy. Some estimates show that green hydrogen prices could fall from today's $6 per kilo to less than $1 by 2050, making it competitive with the current prices of natural gas. Green hydrogen could someday be shipped around the world to places with less access to cheap renewable energy sources. Japan is already working on the supply chain for a clean hydrogen market: It has pilot projects underway with Saudi Arabia, Brunei, and Australia.

## EMERGING PLAYERS

- Ørsted
- Vattenfall
- European Renewable Energy Directive
- NextEra Energy
- Siemens Gamesa
- Everfuel



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2ND YEAR ON THE LIST

# Grid Management

Smart technologies will help balance the power grid.

## 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, combined with a failure to maintain or expand these grids, will pose new challenges over the next two decades.**

## EXAMPLES

China rationed electricity in December as unexpected cold temperatures and rapid post-COVID-19 economic recovery created a surge in energy demands. More than 67 million people had reached the electricity grid's maximum load in the province of Hunan, and local media reported a 3 million to 4 million kilowatt deficit of energy during winter's peak period. While the cold challenges China, increasing temperatures strain California. Rolling blackouts in 2020 and early 2021 impacted hundreds of thousands of homes and businesses. Coupled with wildfires that strain the grid and create solar energy shortages, California faces a growing energy crisis. Climate change has introduced drier, hotter weather to some unexpected parts of the world, while in other areas ice and subzero temperatures have suddenly become more common. Our power networks were never designed with these fast-changing environmental realities in mind.

## DISRUPTIVE IMPACT

Grid failures cost millions and put lives in danger. Utility company equipment isn't being repaired or modernized fast enough, and maintenance will become more difficult amid climate change and new power demands. The U.S. hasn't engaged in long-term planning and has no comprehensive national electricity policy. Remote work may help alleviate strain—U.S. power consumption dropped 4% in the first half of 2020—but it won't offset the impact of climate change. Massachusetts Institute of Technology outlined steps to preempt problems, including incentivizing renewables, artificial intelligence-based predictions about usage, expanding wide-area transmission planning, and conserving energy. AutoGrid and Origami Energy make software to help optimize grids. XENDEE and Worley created cloud software for microgrids. Energy storage will continue to evolve: Northwestern University and German scientists are developing "singlet fission" technology to generate more electricity from solar cells.

## EMERGING PLAYERS

- AutoGrid
- Bloom Energy
- Lition
- Origami Energy
- Stem



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4TH YEAR ON THE LIST

# Charging Stations

Infamous gas-guzzler Hummer will return in 2022 as an electric vehicle.

## KEY INSIGHT

**In the coming years, an unprecedented number of charging stations for electric vehicles will come online, driving demand for a new kind of car and disrupting the supply chain and retail business of traditional gasoline.**

## EXAMPLES

Governments, utilities, and third-party companies are installing networks of charging stations, a process that involves lots of red tape and requires dealing with local utilities and real estate owners. The U.S. had more than 78,000 charging outlets and 25,000 charging stations for plug-in electric vehicles in March 2020. California, Oklahoma, New York, and Colorado also plan to invest in networks of electric charging stations. Electrify America will install charging stations at 100 Walmart stores in 34 states. ChargePoint will open 2.5 million charging stalls by 2025, up from 53,000. EVgo created a modular fast-charging station that can be installed in a matter of days. Google Maps, ChargePoint, and PlugShare use smartphone apps to show the prices, locations, and types of charging ports available, and let people rate and review them.

## DISRUPTIVE IMPACT

Auto manufacturers will invest an estimated $225 billion to electrify their fleets in the next few years, including the new Audi e-Tron; Ford Mustang Mach-E; Mercedes EQS; BMW i3, i4, iX3, and iNext; Volvo Polestar 2; and General Motors' Hummer.

The expansion of charging stations will have a chilling effect on independent and corporate gasoline station chains and the local communities they support. The demand for oil took a significant hit in 2020, and car sales dropped. But the shift toward electric vehicles accelerated. The pandemic may be a turning point for the electric car industry.

## EMERGING PLAYERS

- Blink Charging
- ChargePoint
- Electrify America
- Envision Solar
- Wawa



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3RD YEAR ON THE LIST

# Renewable Energy

Geothermal energy offers an alternative to petroleum.

## KEY INSIGHT

**Renewable energy is collected from sources that can be replenished on a reasonable timescale. Renewable sources include wind, tides, geothermal heat, and sunlight. In many markets around the world, renewable energy is already cheaper than nonrenewable energy.**

## EXAMPLES

Renewables are "the fastest growing source of electricity generation," according to the U.S. Energy Information Administration. In 2019, 400 global corporations committed to climate protection and sustainability goals, while 63 promised to convert 100% of their energy use to renewables. The amount of clean, renewable energy bought by some of the world's largest companies tripled between 2018 and 2020, and more than 100 global cities report they get 70% of their energy from renewables. In September 2020, Chinese President Xi Jinping announced that his country is committed to becoming carbon neutral by 2060. The Biden administration is poised to roll out an ambitious $2 trillion plan to reach net-zero domestic carbon emissions by 2050. Even oil-rich Saudi Arabia is working on a detailed, long-term plan to diversify its economy and move away from oil.

## DISRUPTIVE IMPACT

Renewables will have greater importance in the coming decade. On his first day in office, President Biden signed executive orders signaling a commitment to renewables. Interest in cleantech is growing in China, Singapore, the Middle East, and Norway amid a global shift toward energy efficiency and lower carbon emissions. The International Energy Agency projects that those regions and countries will account for about 40% of energy distributed through the global power grid by 2040. A new value chain is emerging, buoyed by policy, and representing new business opportunities—and headaches for traditional petroleum companies.

## EMERGING PLAYERS

- Energy Vault
- First Solar
- NextEra Energy
- SolarEdge Technologies
- Sunrun



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4TH YEAR ON THE LIST

# Ultra-High-Voltage Direct Current and Macro Grids

Macro grids could be the future of distributed, renewable energy.

## KEY INSIGHT

**In the near future, we will transport clean energy from production sites to destinations in need using a new kind of power grid now being tested in China.**

## EXAMPLES

China invested $88 billion to build macro grids and a new kind of transmission system—ultra-high-voltage direct current (UHVDC). The nation turned on its first 800,000-volt line, covering the east-west expanse of the country and carrying enough energy to power half of Spain. China plans to transport clean energy all around the world, and its Belt and Road Initiative could facilitate that effort. Fifty years from now, we may rely more on China than on OPEC countries (Saudi Arabia, the United Arab Emirates, Venezuela, Iraq, Iran, Kuwait, Libya, Nigeria, Qatar, Algeria, Angola, and Ecuador) for our energy needs.

## 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 could impact where businesses operate.

## EMERGING PLAYERS

- ABB
- TransWest Express Transmission Project
- Macro Grid Initiative
- State Grid Corp. of China



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2ND YEAR ON THE LIST

# Zero-Carbon Natural Gas

Net Power's demonstration plant in La Porte, Texas.

## KEY INSIGHT

**Zero-carbon natural gas is produced at plants that capture all carbon dioxide byproduct, neutralizing the carbon output of the process.**

## 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. While the tech has been around for decades, it has not been deployed at scale. In 2019, startup Net Power successfully built a prototype plant that ran a full cycle without releasing troublesome emissions into the air. The company hopes to scale up to a full-size plant by 2021. New tax credits of up to $50 for each metric ton of emissions captured and stored by a power plant or factory will likely help accelerate wider adoption of this technology. Net Power is a collaboration between Exelon Generation, energy construction company McDermott International, technology developer 8 Rivers Capital, and Oxy Low Carbon Ventures.

## DISRUPTIVE IMPACT

Natural gas produces roughly 32% of U.S. electricity and 20% worldwide. That translates to a significant amount of carbon emissions. With new CSS technology, carbon-free energy could be produced from fossil fuels much more cheaply than via nuclear power plants, and new plants could be booted up as needed without having to wait for power sources that are in long-term development (such as fusion). The popularity of net-zero natural gas will be driven by demand for all that captured and stored CO2. Industrial manufacturers that work with carbon-based materials are prime buyers.

## EMERGING PLAYERS

- Net Power
- Exelon Generation
- McDermott International
- 8 Rivers Capital



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2ND YEAR ON THE LIST

# Floating Nuclear Power Plants (FNPPs)

**The Akademik Lomonosov is a floating nuclear power plant that holds two nuclear reactors and is stationed in the Chukotka Autonomous area on Russia's Arctic coast.**

Photo courtesy of Lev Fedoseyev/TASS.

## KEY INSIGHT

**Floating nuclear power plants (FNPPs) are a new kind of energy plant that can float and move with currents, while also withstanding harsh environmental conditions.**

## EXAMPLES

In an attempt to increase nuclear proliferation, Russia launched an FNPP called the Akademik Lomonosov in 2020. It is loaded with two nuclear reactors and began producing energy last year. Now, Russia is planning a new fleet of FNPPs that have even greater power capacity and could operate for up to 10 years without requiring maintenance of any nuclear reactors. The plants' crews would be stationed onshore. Rather than FNPP barges being stationed off the coast of cities with high power demand, they would deploy on a project basis. For example, Russia hopes to construct an FNPP to generate power for one of the world's largest copper and gold deposits, the Baimsky Mining and Processing Plant.

## DISRUPTIVE IMPACT

Nuclear power generation is risky, but it presents an advantage: You can fix the cost of electricity for the duration of a project, since this type of energy is not subject to market risks and volatility.

## EMERGING PLAYERS

- Akademik Lomonosov
- RusHydro
- Rosatom



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# Climate

7TH YEAR ON THE LIST

# The Anthropocene Epoch

Humans have left a permanent mark on the planet.

## KEY INSIGHT

**We are in a new geological epoch defined by the permanent impact that humans have had on Earth: The "Anthropocene" (anthro for "man," and cene for "new"). Our previous epoch, the "Holocene," began 11,700 years ago just after the last ice age. By defining our current stage of history and the change it represents, we can set a different—and hopefully improved—trajectory for life on Earth.**

## 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 underlying sedimentary and rock layers beneath the surface of the planet. In 2018, an international, independent team of scientists, called the Anthropocene Working Group, found enough evidence to support the official declaration of a new geological epoch. Despite early debate, concrete, publicly available research now corroborates the designation. Humans have left a permanent mark on the planet with chemicals and industrial waste, pavement, plastic, nuclear fallout, everyday garbage, pesticide runoff.

## DISRUPTIVE IMPACT

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 the earth is the first step in studying the implications for our planet's future. Every aspect of life on Earth could be affected. We will need collective and collaborative action from governments and industry if we hope to counteract the planetary damage already done.

## EMERGING PLAYERS

- Anthropocene Working Group
- International Union of Geological Sciences
- The Nature Conservancy
- Union of Concerned Scientists
- U.S. Geological Survey



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2ND YEAR ON THE LIST

# Reversing Environmental Rules and Regulations

President Joe Biden signed an executive order on the international Paris climate agreement just hours after his inauguration on Jan. 20, 2021.

## KEY INSIGHT

**While citizens demand action on climate change, some world governments are now relaxing or eliminating rules and regulations designed to mitigate human-caused environmental damage.**

## EXAMPLES

The Trump administration rolled back more than 100 environmental rules and regulations during its single term, according to U.S. Environmental Protection Agency research. In June 2020, Trump repealed the 50-year-old National Environmental Policy Act, which requires federal agencies to consider the environmental effects of proposed projects before approvals. This effectively cut the timeline for reviews and eliminated requirements meant to limit environmental harm. The Trump administration also replaced the Obama-era Clean Power Plan, which set strict limits on carbon emissions from coal- and gas-fired power plants, and instead allowed states to set their own rules. It cut the reach of the Clean Water Act, removing federal protections for millions of miles of streams and about half of America's wetlands. On his first day in office, President Biden rejoined the Paris Climate Accord, undoing the Trump administration's exit.

## DISRUPTIVE IMPACT

Scientists warn that as temperatures and sea levels rise faster than originally projected, climate change will drastically change life as we know it, disrupting our global food supply, threatening human health worldwide, and limiting our ability to work and travel. Before COVID-19, the World Health Organization identified climate change as the greatest threat to global health in the 21st century, noting that environmental degradation might allow a spectrum of diseases to flourish. Many international initiatives aim to combat and mitigate the effects of climate change, but each country ultimately designs and implements its own regulations. As calls for climate action grow, the public and private sectors may increasingly conflict with one another—but perhaps also align.

## EMERGING PLAYERS

- C40 Cities
- Climate Justice Alliance
- Extinction Rebellion
- Indigenous Environmental Network
- Union of Concerned Scientists



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2ND YEAR ON THE LIST

# Green Stimulus Plans

Rep. Alexandria Ocasio-Cortez (D-NY) speaks as she and Sen. Ed Markey (D-MA) unveil the Green New Deal resolution.

## 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.**

## EXAMPLES

Green stimulus plans have been introduced in China and Europe. In China, both electric vehicle charging and mass transit were identified as new infrastructure that will receive priority stimulus investments. China has also published a number of energy-efficient infrastructure goals—though it has rolled back regulations on coal power capacity. The European Union's executive branch developed a stimulus plan of 750 billion euros, with 100 billion euros allocated to efforts at reaching zero carbon emissions. Meanwhile the U.S. Senate passed a $2.2 trillion stimulus package with no earmarks for green technology or initiatives. But that's going to change: With unified control of Congress and the White House, Democrats plan to pass a version of the Green New Deal that was previously introduced.

## DISRUPTIVE

At the moment, job creation for green R&D investments is low relative to other industries. However, public funding in the U.S., Europe, and China for clean energy research and infrastructure development will lead to new job creation and produce high long-term economic returns—while mitigating climate and environmental challenges. Carbon capture and removal, industrial decarbonization, water reuse, desalination, and energy storage are just a few areas that can be targeted with green stimulus plans, which mean new opportunities for businesses.

## EMERGING PLAYERS

- League of Conservation Voters
- ClearView Energy Partners
- U.S. Federal Electricity Regulatory Commission
- U.S. Rep. Alexandria Ocasio-Cortez (D-N.Y.)
- U.S. Sen. Edward Markey (D-Mass.)
- International Energy Agency
- Data for Progress
- The Democracy Collaborative's Climate and Energy Program



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1ST YEAR ON THE LIST

# Large-Scale Direct Air Capture

The world's largest Direct Air Capture (DAC) and sequestration facility.

## KEY INSIGHT

**Direct air capture technology extracts carbon dioxide directly from ambient air rather than capturing it at sites where it is created, like factories and certain power plants. The CO2 can be permanently stored in deep geological formations or used to produce new industrial products, such as fuels and chemicals.**

## EXAMPLES

Climeworks, Global Thermostat, and Carbon Engineering are developing direct air capture systems to vacuum CO2 molecules from the air. Aiming to spur the reusable CO2 marketplace, CarbonX offered a $20 million prize to companies that develop innovative ways to use captured CO2. In 2020, Microsoft announced a new $1 billion fund for "carbon reduction, capture, and removal technologies" to help offset the company's historic emissions. In January 2021, Tesla CEO Elon Musk announced a $100 million prize for carbon capture technology.

## DISRUPTIVE IMPACT

In early 2021, the concentration of CO2 in the atmosphere was the highest ever recorded in human history. CO2 leads to global warming, and that has a cascading effect on business and society. Increasing attention to direct air capture through big investments will galvanize movement in the near future. As startups prove their technology, new and bigger markets will be built, which means a greater value for captured gas—and ultimately another tool to help mitigate the effects of climate change.

## EMERGING PLAYERS

- Climeworks
- Global Thermostat
- Carbon Engineering
- Microsoft
- Elon Musk
- Intergovernmental Panel on Climate Change
- Southern Green Gas
- Commonwealth Scientific and Industrial Research Organisation
- Occidental Petroleum
- Bill Gates



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3RD YEAR ON THE LIST

# Unpredictable Sea Level Rise

**A mother and child wade through dangerous waters in Jakarta, Indonesia.**

Image courtesy of the World Meteorological Organization/Flickr.

## KEY INSIGHT

**We're getting better at understanding how ice sheets and sea levels change over time. In the years ahead, there will be more focus on trying to measure, interpret, and intervene in the rate of change.**

## EXAMPLES

In 2020, Eastern Siberia recorded the hottest temperatures ever in the Arctic Circle, which melted sea ice and delayed by two months the usual Arctic freeze. Meanwhile, historic floods ruined millions of acres of farmland, and coastal flooding wrought havoc in Alabama and Mississippi. In 2019, 100 scientists began studying the Thwaites Glacier and its melt-off that threatens coastal areas, including Manhattan.

New scientific models and artificial intelligence may help us understand and predict sea levels and human migration patterns: The University of Southern California predicts mass migration to Atlanta, Houston, Dallas, Denver, Las Vegas, and other landlocked urban centers as well as rural Midwestern areas. The federal Global Change Research Program predicts heavier rainfall, 8-foot sea level increases in the next century, earlier spring snowmelt, reduced snowpack, and chronic, long-term drought.

## DISRUPTIVE IMPACT

It is difficult to overstate how significantly rising sea levels will impact human and animal migration, the global supply of food, and our ability to move around. It could reshape countries and trigger mass-scale human migration. Scientists at the Grantham Institute—Climate Change and Environment at Imperial College London warn that the sea could rise higher than the current 2100 estimates if climate change proceeds unchallenged.

To protect against flooding, the San Francisco International Airport will build a 10-mile-long wall, and the U.S. Army Corps of Engineers may create a 6-mile-long barrier in New York City. Fast-rising sea levels along the Gulf and East coasts of the U.S. may lead to $1 trillion in mitigation, repair, and relocation costs. Insurers, city planners, businesses with global supply chains, and any business that relies on or provides logistics should be monitoring this trend carefully.

## EMERGING PLAYERS

- British-American International Thwaites Glacier Collaboration
- ClimaCell
- Opti
- Piccard.ai
- Union of Concerned Scientists



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3RD YEAR ON THE LIST

# Extreme Weather Events

**Extreme weather events will continue to plague communities in the future.**
Image courtesy of @bwc/Flickr.

KEY INSIGHT

**An extreme weather event 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 five years on Earth have been the hottest on record, with average temperatures having risen 1.8 degrees Fahrenheit in the past 115 years, the warmest period in modern civilization. The Oeschger Centre for Climate Change Research at Switzerland's University of Bern analyzed global temperatures over 2,000 years and found that, despite short periods of cooler temperatures, the Earth is warming faster than at any other time in the past two millennia.

The result: extreme weather. A 2019 Bulletin of the American Meteorological Society report confirmed the link between the earth's rising temperature and extreme weather events, based on the views of 120 scientists from 10 countries and 17 peer-reviewed analyses with historical observations and model simulations.

The repercussions have been devastating. The 2019–2020 Australian bushfires killed millions of animals, destroyed more than 12 million acres, and cost $110 billion in damages. Last year, 22 U.S. weather and climate disasters caused $1 billion in losses each, and California's fires alone scorched 4.1 million acres, up from the previous state record of 1.9 million in 2018. India, meanwhile, has experienced 310 climate events in the past 15 years, after only 250 climate events from 1970 to 2005.



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# Extreme Weather Events continued

A historic snowstorm hit Texas in 2021.

## DISRUPTIVE IMPACT

Extreme weather is the new normal. NOAA's National Centers for Environmental Information also found that tropical storms move more slowly than they did 40 years ago, lingering longer and causing more damage. The United Nations' scientific panel on climate change issued a dire report warning that environmental disruption may lead to a dystopian future of food shortages, wildfires, extreme winters, spread of diseases, a mass die-off of coral reefs, and more—as soon as 2040. That's less than 20 years from now.

Large natural disasters can slow regional economic growth for decades, hinder corporate and industrial productivity, and lead to post-traumatic stress among survivors. Extreme weather can shift infectious disease patterns and compromise food security, safe drinking water supply, and clean air. It can drive up construction costs and cause flight cancellations and will challenge insurers to build new models to better estimate risk and repercussions. New R&D initiatives, emerging green technologies, climate-focused investment strategies, and global coalitions could help mitigate extreme weather. Businesses can do right by their investors and the planet by curtailing contributions to climate change.

## EMERGING PLAYERS

- Chooch Intelligence Technologies
- DroneSeed
- Jupiter
- Ladera Tech
- Severe Weather Information Centre



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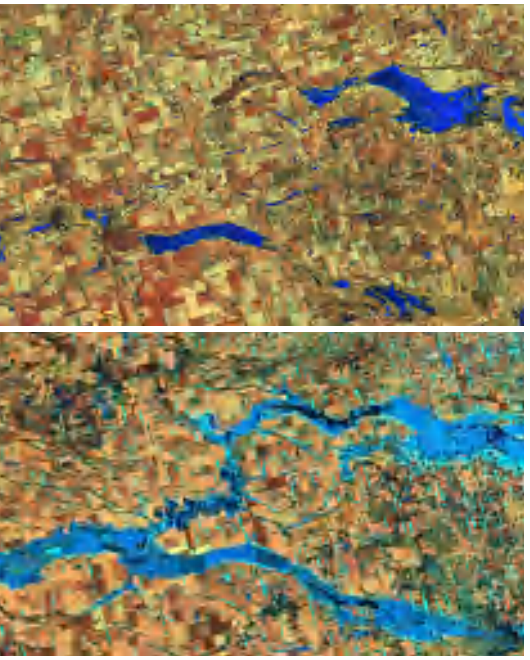
4TH YEAR ON THE LIST

# Human Migration Patterns Shift



These images show a portion of the James River in eastern South Dakota. The 2015 image depicts the river in a typical spring, while the 2020 image shows its banks overflowing; this and other sections of the river had been at flood level since spring 2019.

Image courtesy of NASA Earth Observatory.

## KEY INSIGHT

**There's no official designation for "climate change refugees," but there may be one soon, as climate change forces more people from their homes and communities, undermining the economic stability of those regions. Europe could receive 1 million climate refugees annually by 2100, forcing unimaginable changes to cities and infrastructure.**

## EXAMPLES

Last year, climate disasters uprooted 9.8 million people and became the leading cause of internal displacement around the world. Climate change will force 63 million South Asians and 1.7 million Mexicans from their homes by 2050, while another 1.5 million Ethopians will have to search for new sources of food and water. Expect a wave of migration from Africa, the Indian subcontinent, and from island nations into Europe and the U.S. Meanwhile, the U.S. joined Bangladesh, Italy, Ethiopia, Hungary, Greece, and Lebanon in implementing historic limits on refugee resettlement. Pushbacks of asylum seekers at the border, curfews in refugee camps, and anti-migrant rhetoric have risen alongside displacement.

## 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. A recent World Bank report projected climate change could result in 143 million "climate migrants" by 2050, as people escape crop failure, water scarcity, and rising seawater. Most of them will flee developing countries in sub-Saharan Africa, Latin America, and South Asia. The World Bank offered a glimmer of hope: The future may not be as bleak if we work now to cut greenhouse gas emissions drastically and lay plans to increase education, training, and jobs for migrants. Intergovernmental organizations need to adopt an official designation—as well as necessary protocols—for near-future waves of climate refugees.

## EMERGING PLAYERS

- Chatterbox
- Funzi
- Jobs4Refugees
- Mygrants
- Startup Refugees



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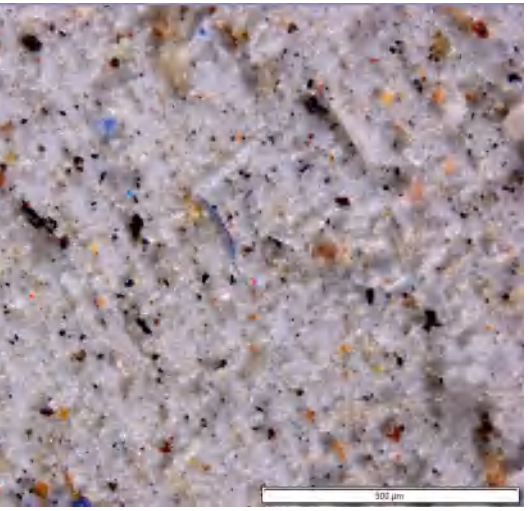
1ST YEAR ON THE LIST

# Plastic Rain



**Microplastics found in rainwater, collected by researchers in the Western U.S.**

Image courtesy of Utah State University.

## KEY INSIGHT

**Plastic rain is the new acid rain. Microplastics are floating through our waterways, being carried into seawater and evaporating into clouds, which then disperse and redistribute the plastics in rain—even in protected natural habitats like the French Pyrenees.**

## EXAMPLES

In 2020, the journal Science published alarming new research: After a 14 month study of rainwater, scientists found more than 1,000 metric tons of microplastic particles in the water—or about the equivalent of 120 million plastic water bottles. That's a stunning amount of plastic given the small and remote area the researchers covered in the Western U.S. Microplastics present unique challenges, because they can't be easily captured in a big net, and we can't apply current water filtration technology at an oceanic scale.

## DISRUPTIVE IMPACT

As emerging markets grow, water bottles will follow. And as the middle class grows in developing countries, the use of plastics in packaging, food, and drinks is expected to double our current use in 10 years. Plastic particles are just about everywhere: our deep-sea ecosystems, our freshwater reservoirs, our commercial farms, and our wildlife. Microplastics eventually degrade into nanoplastics, making them impossible to detect but no less environmentally damaging. Worse, scientists don't yet know the long-term effects of breathing in or swallowing nanoplastics—though microbes and viruses are certainly capable of hitching a ride on tiny plastic particles. A new crop of startups hopes to tackle the dual problems of particle identification and smaller-scale filtration. Parverio is developing a rapid testing and filtration system to pull microplastics out of local water supplies.

## EMERGING PLAYERS

- U.S. National Oceanic and Atmospheric Administration
- European Chemicals Agency
- Parverio
- Nanomembrane Research Group



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1ST YEAR ON THE LIST

# Plummeting Biodiversity

**Tiny, inconspicuous purple burrowing crabs feast on cordgrass and threaten local ecosystems.**
Photo courtesy of Mark Bertness.

## KEY INSIGHT

**We're living through a strange contradiction: It may seem as if we're in close contact with an ever-increasing number of wild animals and novel pathogens, but in reality our planet's biodiversity has plummeted.**

## EXAMPLES

The human race accounts for less than 0.01% of the biomass on Earth. We physically make up less than one ten-thousandth of all life, in other words—and yet we've already wiped out 83% of the planet's animal species. The U.N.'s Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services published an apocalyptic dataset last year: 1 million animal and plant species are at risk of destruction. Not 1 million rabbits, or 1 million daffodil plants, but 1 million species. Annihilated. A mass extinction event that is so incomprehensible, no metaphor or analogy suffices. The dramatic decline in species populations is related to habitat loss and degradation, including deforestation, driven by how we produce food.

## 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. Last year, a tiny, inconspicuous purple burrowing crab bred at high levels in places like coastal Massachusetts, feasting on native plants that kept marshland in place, and eventually leading to more sediment in the local water streams, increased flooding during harsh storms, a loss of recreational space for water sports, and the loss of commercial fishing grounds. In fact, the crabs have done so much damage already, you can see it from space. The crabs are now considered a "keystone species," meaning they have a disproportionate impact on the natural environment, and the other species in the ecosystem now depend on them to maintain the current order.

## EMERGING PLAYERS

- International Union for Conservation of Nature and Natural Resources' Red List
- Yale University Office of Sustainability
- The Convention on Biological Diversity



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1ST YEAR ON THE LIST

# Rewilding

The construction of nondisruptive corridors or "ecoducts," like this wildlife crossing in Poland, is a key component of rewilding.

## 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. Jaguars have been reintroduced to Argentina's wetlands, lynx to the Scottish Highlands. Fish and sea life were even brought back to a dead coral reef using underwater speakers broadcasting the sounds of a thriving reef. The restoration process is facilitated by technological innovation, including the use of biomimicry devices to non-invasively influence animal behavior, and the replacement of radio receivers with GPS trackers to enable superior monitoring systems. Another key aspect of rewilding is to preserve corridors that provide safe passage for nature to spread from one region to another. These efforts include the rehabilitation of natural corridors such as the Côa Valley in Portugal, as well as the construction of "ecoducts" like the crossings at Canada's Banff National Park and the crab bridges and tunnels of Christmas Island.

## 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.

## EMERGING PLAYERS

- The Rewilding Institute
- Rewilding Europe
- Yale School of the Environment
- Zoological Society of London's Instant Wild platform
- Peace Parks Foundation
- U.S. National Park Service Office of International Affairs



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2ND YEAR ON THE LIST

# Seasteading

**An artist's rendering of Oceanix City, an adaptable, sustainable solution for human life at sea.**
Image by Oceanix/Bjarke Ingels Group.

## KEY INSIGHT

**Seasteading is a colonization process wherein permanent human dwellings and settlements are constructed at sea, outside the reaches of most governments.**

## EXAMPLES

The pandemic has accelerated what had been a very small anarcho-capitalist movement to build new communities that operate outside any traditional government. The threats of government-enforced lockdowns, mandatory contact tracing, and digital surveillance have been cited as motivating factors for seasteading groups. 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. Danish architect Bjarke Ingels is working on Oceanix City, an interlocking system of hexagonal islands powered by renewable energy. In Panama, Ocean Builders is laying the foundations for a factory that will house the largest 3D printer in Central America, and produce the materials necessary for floating homes.

## 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, incorporating renewable energy sources, indoor vertical farms, and underwater communications systems.

## EMERGING PLAYERS

- Seasteading Institute
- Ocean Builders
- Oceanix



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8TH YEAR ON THE LIST

# Green Tech

Concept of a future green living space by Vincent Callebaut.

## KEY INSIGHT

**To counteract extreme weather and climate change, researchers are looking to green technologies to reduce our short- and long-term impacts on the environment.**

## EXAMPLES

Siemens will build a wind farm in Ethiopia that will power more than 400,000 households. In the U.S., a clean power agreement could spur $1.2 billion in wind and solar energy projects in Nebraska. Pandemic and blackout fears catalyzed a $50 billion market for rooftop solar panels. Amazon will buy a fleet of electric vans to start delivering packages to customers in 2021, with 100,000 operating by 2030. More green tech projects are on the horizon, as sustainability becomes a post-COVID-19 recovery strategy. Apple co-founder Steve Wozniak launched Efforce, a blockchain-based energy platform to fund energy-efficiency projects. Its token offering hit a market cap of $950 million in 13 minutes. DroneSeed is tackling rapid reforestation with heavy-lift drone swarms that spread patented seeds in wildfire-ravaged areas.

## DISRUPTIVE IMPACT

Climate change and new regulatory efforts could force the world to look for new, sustainable sources of energy. Green tech is still a young market, but plenty of new technologies and scientific breakthroughs have generated significant buzz. Investments are growing as more governments pledge funding for green tech solutions that double as economic recovery efforts.

## EMERGING PLAYERS

- CO2 Solutions
- Blue Planet
- Efforce
- Fuergy
- Facedrive
- Lilium
- Power Ledger
- OceanX



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# Green Tech Trends

> The greatest danger to our future is apathy.
>
> — Jane Goodall, primatologist

### 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.

### CO2-Based Industrial Materials

Carbon dioxide captured from factories can be repurposed as building materials. Startup Blue Planet developed a way to convert carbon dioxide into a synthetic limestone that can be used as an industrial coating or mixed in with concrete. The company's bicarbonate rocks were included in the reconstruction of San Francisco International Airport.

### Plastic-Eating Enzymes

In 2019, researchers at the University of Portsmouth accidentally discovered a plastic-eating enzyme that could help break down larger pieces of plastic and aid in recycling efforts. French biotech company Carbios will produce a new generation of plastics for bottles, packaging and film that include enzymes that trigger biodegradation after use. Recycling Technologies, based in the U.K., hopes to deconstruct traditionally unrecyclable plastics into "plaxx," or virgin plastic, wax and oils.

### Smart Ocean Filters

The notorious pile of trash floating in the Pacific Ocean is bigger than we thought. 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. An estimated 5 trillion pieces of plastic float in the ocean, an amount so large that environmentalists called on the United Nations to declare the garbage patch its own country dubbed "The Trash Isles." A recent report by the British government warned that the amount of plastic in the ocean could triple by 2050. The problem prompted some innovative approaches to cleaning up the trash. In the fall of 2018, the Dutch nonprofit Ocean Cleanup launched an ambitious effort to clean up half of the garbage patch within five years by using a fleet of 60 autonomous floating "screens," or nets that collect debris as small as a centimeter in diameter. Algorithms pinpoint where to deploy the screens, and real-time telemetry monitors the condition, performance, and trajectory of each one, before boats eventually retrieve them. The system relies on natural ocean currents for energy; the rest of the electronics are powered by solar energy. Another effort, The Seabin Project, cleans up oil and trash using floating garbage cans with pumps and filtration centers set up in harbors, marinas, and other busy areas. The project retrieves plastic that otherwise could have trapped animals and caused problems if ingested.

### Ocean Fertilization

Oceanic iron fertilization involves dumping enormous amounts of iron sulfate into large swaths of the ocean. Theoretically, it would stimulate the growth of phytoplankton, the tiny sea life that absorbs carbon dioxide, releases oxygen, and gets gobbled up by other creatures. This is key, because every year the ocean absorbs about a quarter of global carbon dioxide emissions—which in turn changes water chemistry and harms marine ecosystems.

### Sandcastling Glaciers

Sand is stronger than we once thought. A conservation project from Princeton University seeks to build massive piles of


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# Green Tech Trends

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

Some scientists are working on building enormous, mirrored parasols in the stratosphere, which would reflect sunlight back into space and theoretically cool the Earth's atmosphere over time. The Keutsch Research Group at Harvard University is hoping to launch the first ever aerosol injection experiment known as the Stratospheric Controlled Perturbation Experiment. The scientists will use a high-altitude balloon to inject aerosols, or extremely fine particles, into the upper atmosphere, where they can reflect sunlight. Once it is in place, the balloon can release enough material to create a perturbed air mass roughly 1 kilometer long and 100 meters in diameter; the same balloon can then measure resulting changes in the perturbed air mass, including changes in aerosol density, atmospheric chemistry, and light scattering.

## 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 top climate scientist at the U.S. National Oceanic and Atmospheric Administration received $4 million from Congress—as well as permission—to develop the technique, as well as another using sea salt particles, if the U.S. and other nations fail to reduce global greenhouse gas emissions.

## Cloud Injections

Inspired by maritime observations, this geoengineering technique would try to re-create the long clouds left by ocean freighters passing through open water. An aerosol of sea salt particles and seawater vapor would be injected into these clouds, which would expand and shade our oceans. The director of the chemical sciences division of NOAA's Earth System Research Laboratories received a $4 million grant from Congress and permission to study sea salt vapors. Scientists at the University of Washington are working on increasing the whiteness and brightness of the clouds by spraying seawater into them. Swiss scientists, meanwhile, are developing ways to eliminate cirrus clouds—those thin, wispy clouds made from ice crystals that form at high altitude and trap heat in the atmosphere. Other efforts to reflect sunlight include painting everything from building roofs to mountainsides white, and laying reflective sheets in deserts.

## 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.



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3RD YEAR ON THE LIST

# Environmental, Social, and Corporate Governance (ESG)

A biowall covers a skyscraper in Sydney.

## KEY INSIGHT

**Companies of all sizes are leading with sustainability as part of their core values. Environmental, social, and corporate governance (ESG) refers to core factors in evaluating the sustainability and societal impact of a company or an investment.**

## EXAMPLES

Last year, PepsiCo adopted the United Nations Business Ambition for 1.5 Degrees C pledge, and Allbirds and Kickstarter applied for certification under the Climate Neutral certification program by completing a carbon footprinting exercise and buying offsets to counteract their environmental impacts. General Mills launched regenerative agriculture programs with 24 wheat farmers in Kansas and 45 oat farmers across North Dakota, Saskatchewan, and Manitoba.

## DISRUPTIVE IMPACT

A study last year by BNP Paribas showed that sustainability has become a major focus across many industries; since the onset of the pandemic, a quarter of respondents became more focused on sustainability measures within their organizations. Many companies see sustainability as a value-add for all of their key stakeholders. Other companies can follow suit by developing long-term strategy, vision, and R&D plans to create new business opportunities, which create value for shareholders while also helping the planet. Corporate sustainability is a growing concern among consumers and investors who hope to see both economic value and good-faith efforts to mitigate business's role in climate change.

## EMERGING PLAYERS

- Kansas regenerative agriculture program
- Climate Neutral
- Dassault Systèmes
- Autodesk



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# Environmental, Social, and Corporate Governance (ESG) Trends

> There comes a time when humanity is called to shift to a new level of consciousness ... that time is now.
>
> — Wangari Maathai, environmental activist

## Strategic Sustainability Plans

Unilever's Sustainable Living Plan sets 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

Many elements of a supply chain that can hinder sustainability, including energy use, labor conditions, cold-chain carbon emissions, and contamination of local environments. In recent years, the number of companies reporting their environmental, social, and governance (ESG) policies for suppliers has increased dramatically. Refinitiv, a financial and risk solutions company, noted that more than half of the companies in its directory now report ESG policies.

## 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. Shell Oil employs a novel approach to fuel efficiency: 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 electric barges now hum between ports in Amsterdam and Belgium. The vessels, made by Dutch company Port Liner, have been dubbed Tesla ships. Eventually, the hope is that they will operate autonomously. Hybrid boats are making waves, too. Powered in part by solar energy, they are lighter weight and less noisy while boasting greater passenger capacity and lower emissions.


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# Space

14TH YEAR ON THE LIST

# Space and Off-Planet Exploration

Kyoto University and Sumitomo Forestry are developing satellites out of wood.

## KEY INSIGHT

**Human ambition, our quest for knowledge, and our curiosity have always driven our rush to explore space, and 2021 promises to be another important year for space initiatives. Some of the missions are crewed by humans, others feature robots, and a handful will bring earthly agriculture into space.**

## EXAMPLES

Last year was a triumphant one for the space industry. SpaceX successfully launched a mission to the International Space Station—the first such launch from American soil in a decade. Three missions to Mars took flight. And brand-new moon samples were returned to Earth. This year, a number of important missions will further shape our off-planet aspirations. NASA's Mars 2020 mission successfully reached its destination, a point on the planet called the Jezero Crater. The Perseverance rover will look for microbial life forms and test new technologies required to sustain human life. The Hubble Space Telescope's successor, the James Webb Space Telescope, is scheduled to launch in the fall. SpaceX will begin further testing its next-generation vehicle Starship, which is built for deep space exploration.

## DISRUPTIVE IMPACT

Some estimates say the space industry is worth $330 billion and could double by 2026. From leisure travel to asteroid mining to telecom, myriad industries and businesses will spring from and benefit from space exploration.

## EMERGING PLAYERS

- SpaceX
- Blue Origin
- Moon Express
- Astrocast
- Maxar Technologies
- Kyoto University
- Sumitomo Forestry
- Astroscale
- Advanced Quantum Scientific Technology
- BEI Precision
- SpaceFab
- Data Collective
- Boeing HorizonX Ventures
- Planet Labs
- Rocket Lab



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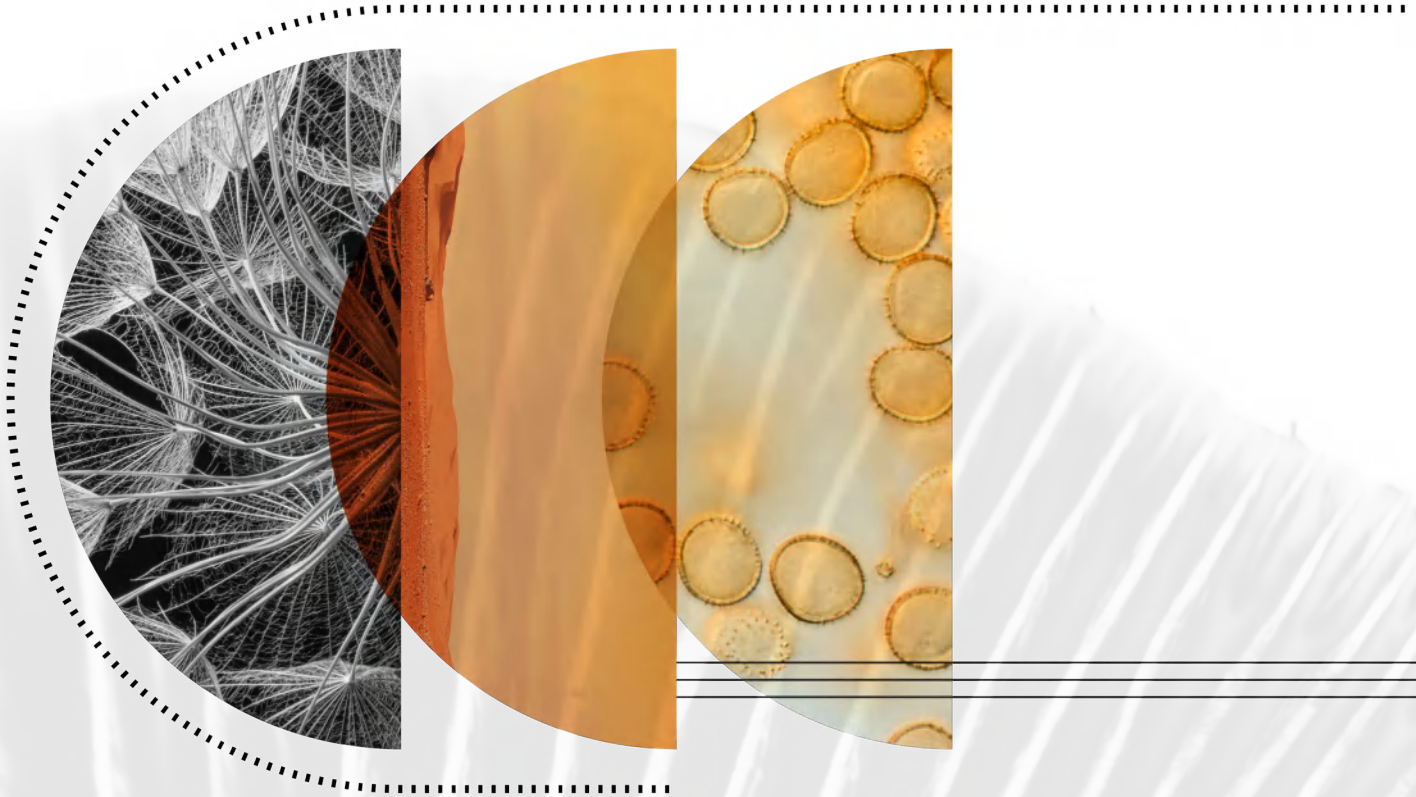

## New World Spores

**Far-future neutral scenario**

Humanity looks beyond Earth and Mars when people begin to think of their future in terms of civilizations rather than years. But new human colonies in the cosmos cannot simply be built—they must be born. To prepare for future colonies, we send highly resilient spores to far-off planets that are deemed able to support life. The spores then have millennia to develop and evolve into basic life forms that could serve as valuable resources for human settlers later on. Sending these microscopic advance teams might be the kind of foresight that gives the explorers of tomorrow a headstart on our next planetary home.



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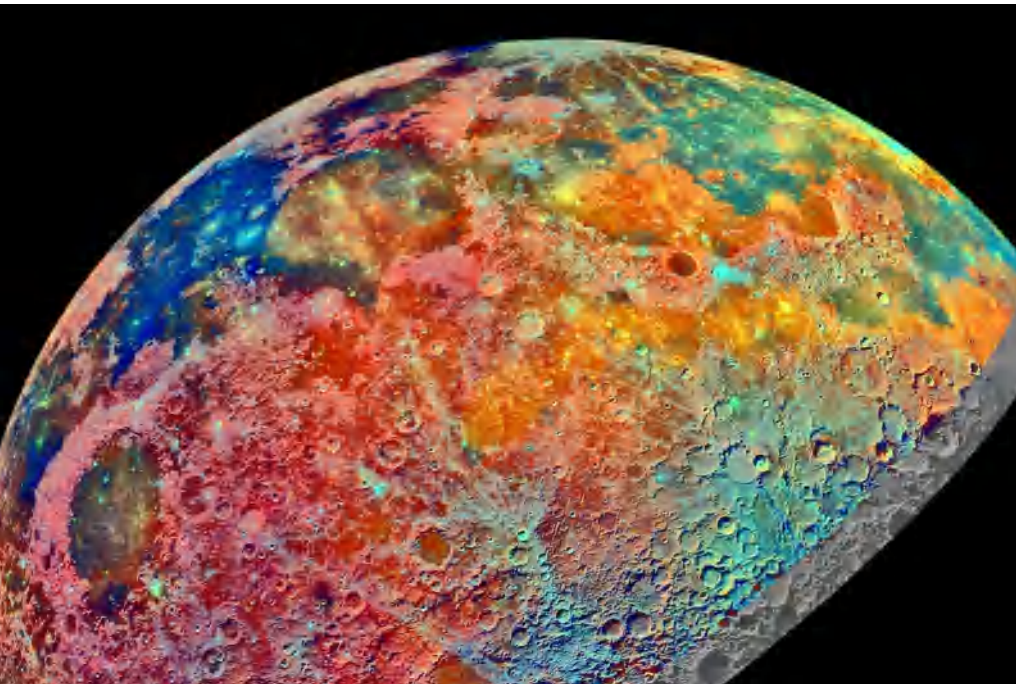
# Space and Off-Planet Exploration Trends



The Earth's moon is made up of many different materials, represented here by different colors.

## Space Mining

Vast amounts of precious rare-earth elements and metals—which are used in much of today's technology hardware—exist on the moon and in meteors and asteroids. 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. In 1979, several members of the United Nations put forward the Moon Treaty, a framework to guide international space exploration, which, among other things, prohibited mining in outer space. None of the world's spacefaring nations ratified the treaty. In 2020, NASA shared the Artemis Accords, an international agreement for civil space and moon exploration. While the agreement has nine signatories, including some of the United States' closest allies, it has also been criticized for promoting commercial mining of celestial bodies. Notably, the other powerful space nations, including China, India, Russia, Germany and France, have not signed on. Whether or not celestial mining becomes a viable business practice in the very near term, the idea of commercial space exploration puts pressure on governments to create clear international agreements and frameworks for governing space.

## Space Junk

Space is our next dumping ground. As many as 170 million fragments of metal and astro debris orbit the Earth. That includes 20,000 pieces larger than a softball and 500,000 about the size of a marble, according to NASA. This debris will pose a navigation hazard for many centuries to come as low-Earth orbit becomes more cluttered. At least 200 objects roar back into the atmosphere each year, including pieces of solar panels, antennas, and fragments of metal. All of them pose dangers for future astronauts: One plum-sized piece of gnarled space trash traveling faster than a speeding bullet could rip a 5-foot hole in a spacecraft. That collision, then, would throw off its own share of shrapnel, which would join the rushing river of junk already circling the planet. In space, collisions beget collisions in a chain reaction known as the Kessler syndrome—a phenomenon that could eventually make some of our available orbits unusable. It's not just Americans doing the dumping—China and Russia each have dozens of decommissioned satellites overhead—although the U.S. certainly does it with style. Where all that junk winds up isn't something we can predict accurately. 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.



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# Space and Off-Planet Exploration Trends

**The Artemis Accords are a set of international agreements for civil space and moon exploration that include language around commercial mining of celestial bodies.**

## Space Sustainability Initiatives

Space junk is becoming a bigger problem as more satellites are launched into the atmosphere. An innovative approach to reducing particulates is already underway at Kyoto University. Sumitomo Forestry, part of Japan's Sumitomo Group, is developing microsatellite constellations with individual units made out of wood. It's not the first time wood has been considered for such a job: NASA's earlier Ranger program sent balsa wood structures to the moon. One benefit is that the wood won't block the electromagnetic waves that satellites use to communicate. The project is set to launch in 2023.

## Space Imaging

In 2019, scientists did what they thought was impossible: They captured an image of a black hole's silhouette using the Event Horizon Telescope. A team of international astronomers and computer scientists spent a decade developing a new kind of technique that revealed a dark black center surrounded by a massive ring of orange and yellow light. In early January, scientists in Maui used the new Daniel K. Inouye Solar Telescope for the first time and took the highest-resolution photos of the sun ever recorded. (The surface looks like the cracked ground of the Atacama desert—if it were oozing and on fire.) New techniques and equipment for space imaging will advance the work of research scientists across many fields.

## Satellite Megaconstellations

Within a few years, there will be vast megaconstellations of tiny satellites orbiting the Earth. In August 2020, the U.S. Federal Communications Commission approved Amazon's latest satellite megaconstellation, which included 3,236 microsats built to provide high-speed internet—that's more than double the total number of satellites currently in orbit. In early 2020, the Starlink constellation, a project from Elon Musk's SpaceX, began sending clusters of 60 satellites into orbit every few weeks. By the end of this year, there could be a fleet of 12,000 overhead. U.K.-based OneWeb is set to launch up to 700. That's just a small selection—it would take several pages to list every company and planned launch over the next five years. 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 microsat and cubesat constellations, in addition to heavier satellites, rockets, and spaceships 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


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# Space and Off-Planet Exploration Trends

equipment. Some commercial spacecraft manufacturers, including SpaceX, are developing new coatings that would minimize reflection and other sources of interference.

### 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 the magnetic field from Earth. Think of it as an invisible sail that could someday enable old satellites to guide themselves home.

### Space-Based Internet

Amazon, SpaceX, Google, and others are developing satellite technology that would beam internet services directly to our devices, and in the process bypass our internet service providers (ISPs). OneWeb has plans to power what it calls "fiber-like internet" coverage in the Arctic. New space-based internet services will rely on a complex array of microsat constellations and ground stations. SpaceX and Amazon are working on services to bring internet service to people in areas neglected by traditional wireless carriers and ISPs.

### The Space Economy

New spacecraft, rockets, and other technologies are helping private commercial companies achieve liftoff—with plenty of eager investors footing the bill. Investors including Morgan Stanley are eying a new space gold rush, now that a critical mass of commercial space companies and their technologies have matured enough to move beyond proof of concept into testing. Some estimate the space economy will grow to more than $1 trillion in the next two decades. We anticipate aggressive investment into commercial space companies, especially in the areas of insurance, satellites, defense, and aerospace technologies and materials (manufacturing and mining).

### Space Tourism

As of 2020, SpaceX became the only NASA-certified company to send people into orbit. While Elon Musk's goal is Mars, shorter flights on Starship could begin in the next year or two (initially round trips to and from Earth). Space Adventures is offering private spaceflight to the International Space Station (ISS) and eventually the moon. Already, Space Adventures has ferried more than a half dozen paid trips to the ISS via a partnership with Russia. In December 2021, two Space Adventures tourists will ride aboard the Soyuz spacecraft.

### Galactic Ride Sharing

New technologies have spawned a new trend in space transportation: galactic ridesharing. In 2018, Spaceflight Industries launched its first rideshare mission called SSO-A SmallSat Express aboard a SpaceX Falcon 9. The company purchased all available payload space on the rocket to service customers who wanted to launch various items into space. These types of launches often include microsats and cubesats from multiple countries, but unusual items make it to space occasionally, too. A satellite from the Los Angeles County Museum of Art sent up a 24 karat gold jar with a bust of the first African American astronaut to reach space. Artist Trevor Paglen sent a self-inflating sculpture that reflects sunlight and can be viewed by the naked eye on earth. Another craft, the Elysium Star 2 sent by Elysium Space, contained the cremated remains of people who wanted to become shooting stars. 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.

### Galactic Refueling Stations

Some satellites require fuel, and it turns out fuel is very heavy. After a satellite runs out, it's no longer fully operational. For that reason, researchers have been developing new refueling stations and new techniques that would overcome some liquid dynamics challenges. Last year, startup Orbit Fab successfully completed the first set of experiments to see if water could be transferred between two satellite test beds. Orbit Fab has been working with satellite manufacturers on something called the Rapidly Attachable Fuel Transfer Interface, or RAFTI, which is a new kind of valve system that would allow satellites to be fueled on the ground before launch and, someday, refueled in space. This would eventually allow more satellites to stay in orbit and help reduce the creation of new space junk.


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# Space and Off-Planet Exploration Trends

**This artist's concept depicts astronauts and human habitats on Mars. NASA's Mars 2020 rover is carrying a number of technologies that could make the planet safer and easier to explore for humans.**
Image credit: NASA.

## Off-Planet Living

NASA has said it wants to send humans to Mars by 2030, and in 2016 it selected six private U.S. companies, including Boeing, Lockheed Martin, and Bigelow Aerospace, to develop prototypes for deep space habitats. At the beginning of the year, Elon Musk talked about sending 1 million people to colonize Mars by the year 2050 using three Starship launches a day. SpaceX has taken steps to turn what sounds like science fiction into reality—this year, the company will bring astronauts to the ISS. However, astrophysicists have been quick to point out difficult hurdles to overcome in Mars-bound space travel, not the least of which is radiation. As Columbia University astronomer Caleb Scharf explained, "In the worst case scenario (which may or may not be a realistic extrapolation) there's a chance you'd end up dead or stupid on Mars. Or both."

## Mercury Rain

New rocket 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 has 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 hovering above us. The U.S. Federal Aviation Administration requires companies to disclose hazardous materials in flight, but its policy also doesn't address satellites. This is an area where, yet again, technology has sped beyond the limits of the law.


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# Space and Off-Planet Exploration Trends

## 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 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.

## 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. In 2021, China will start building a new space station, and it's planning to send astronauts to the moon by 2030. But the country's main focus is on the commercial space industry, as its private space business sets up shop manufacturing cubesat megaconstellations, larger satellites, rockets, IT infrastructure, communications networks, and all the other hardware needed by the global business. While China is a little late to the party compared to other world leaders such as the U.S. and Russia, it's catching up quickly. Last year, China became the first country to land a robotic mission on the far side of the moon. It was a historic accomplishment—and a clear sign of new leadership from China. President Xi Jinping said, "The space dream is part of the dream to make China stronger … the Chinese people will take bigger strides to explore further into space." China doesn't just want to be seen as a powerful Asian nation—it wants to set the global pace for numerous geo-economic initiatives, environmental causes, and societal development.

## 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 scientists 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.

> A geologist once said to me, 'We went to the moon six times. If you had come to New York state six times, would you have thought that you investigated the whole world?
>
> — Jeanette Epps, NASA astronaut



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# Application

## STRATEGY

Throughout every industry, environmental, social, and corporate governance (ESG) and corporate social responsibility initiatives have taken center stage. With the passage of green stimulus plans 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 ESG 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

Our observation: Senior executives are prioritizing sustainability broadly across their organizations, and there have been new calls to funnel sustainability concepts 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

R&D teams within most industries should help executives make decisions about the long-term implications and impacts of ESG plans. Curbing emissions might help meet sustainability goals, for example, while causing unintended complications elsewhere in the business. For teams working in adjacent fields, this year is a good time to hit the white board, especially as green stimulus plans unlock new sources of R&D funding and stimulate outside investment.

## RISK

There are clear risks and dangers associated with climate change. Extreme weather events, flooding, and the outbreak of disease can have catastrophic downstream effects on a company's ability to function. Those working in risk will need new models to calculate the value of ESG and CSR goals—and to determine the costs associated with preserving older operational practices. Chief risk officers can develop thought leadership and strategy to solve energy and climate-related challenges in a way that drives value back to the organization.



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# 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 about the futures of energy use and sustainability. And it's never too early to imagine the future impacts of the new space economy on your organization.

1

**Is our company tracking disruptions related to energy use?**

**These include proposed or new regulations, rebates, and green stimulus plans (domestic and international).**

2

**What parts of our business make us a target for disruption?**

**How could new business models introduced by new entrants pose a threat? And to stretch your foresight capabilities, ask: How could an emerging space economy unlock new opportunities in our industry?**

3

**What assumptions must hold true for our current strategy to succeed?**

**How will we make needed changes?**



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Volume 12 of 12

14th Annual Edition

# 2021 Tech Trends Report

Strategic trends that will influence business, government, education, media and society in the coming year.

- Synthetic Biology
- Biotech
- Agriculture

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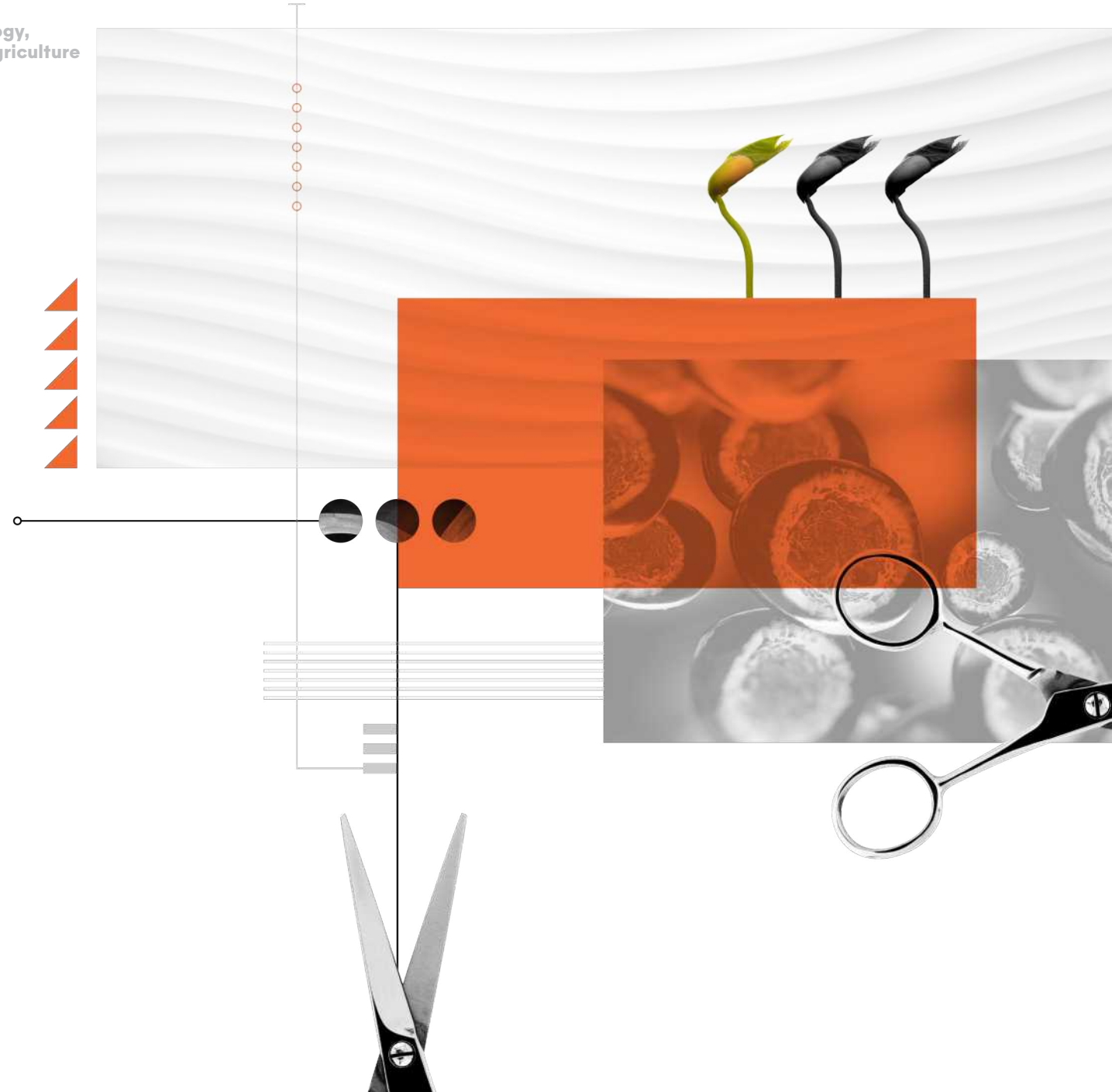

# Synthetic Biology, Biotech & Agriculture Summary

- We have opened the door to the post-natural age. This decade, synthetic biologists are focusing on intentional design, improving organisms, and constructing new materials from life's building blocks.
- Right now, in our guts and in the environment, we are all committing mass murder of microorganisms.
- Researchers are developing a new technique that might someday enable people to upgrade their children before birth.
- Most Americans would sign over rights to their DNA data for $99.
- By 2025, we may be out of data storage space for human genomes.
- Less 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.
- Researchers are using neural networks to develop artificial human genomes.
- You can now sequence your complete genome for $299—less than the price of a TV.
- Scientists created the first genetically modified squid using CRISPR.
- Lab-grown, miniature human brains and lungs are being used to research the lasting effects of SARS-CoV-2.
- This year, millions of genetically engineered mosquitoes will be released in the Florida Keys.
- Researchers are developing a way to store an exabyte of data—roughly a million terabyte-sized hard drives—in a blob of DNA.
- Indoor vertical farms deliver 10 to 20 times the total yield of conventional farms with far less waste, thanks to brighter, cheaper LED light bulbs, cloud-based artificial intelligence systems, and more available agricultural sensors.
- The bug protein market could top $1 billion by 2023.



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> What I cannot build,
> I cannot understand.
>
> — Richard Feynman, theoretical physicist

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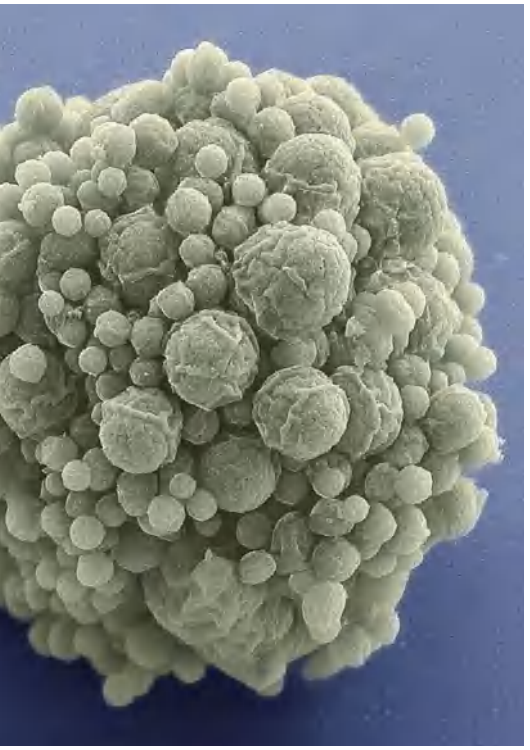
# Synthetic Biology & Biotech

3RD YEAR ON THE LIST

# Synthetic Biology



Syn 3.0 has only 473 genes.

## 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

Researchers are developing standardized biological parts, redesigning proteins, developing new microbes, and producing enzymes and other products—even designing and building unique genomes. In January 2008, the J. Craig Venter Institute (JCVI) created the first synthetic bacterial genome, Mycoplasma genitalium JCVI-1.0, representing the largest synthetic DNA structure ever created. Two years later, they announced the world's first synthetic life form, a single-celled organism made from laboratory chemicals. Swiss researchers showed it's possible to program mammalian cells to do basic math. Researchers at the University of California, San Francisco, engineered E. coli to be programmed to find and move along designated paths.

## DISRUPTIVE IMPACT

Imagine a future where you no longer take medication—instead, your cells are simply reprogrammed to fight off whatever ails you. Or you bite into a thick, juicy tomahawk steak that's grilled to perfection—and vegan-friendly, because it's made from plant-based proteins. Synthetic biology will someday help repair defective genes, rid the planet of toxins, destroy cancer cells, and help mass-produce proteins for our consumption. In the last decade, investors put $26 billion into synbio startups, according to SynBioBeta, the synthetic biology industry hub. Products now underway could generate $4 trillion by 2031.

## EMERGING PLAYERS

- Twist Bioscience
- SynBioBeta
- JCVI
- Synthego
- Sherlock Biosciences
- George Church's lab at Harvard University
- Keasling Lab at the Lawrence Berkeley National Laboratory



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7TH YEAR ON THE LIST

# CRISPR

Jennifer Doudna (right) and Emmanuelle Charpentier won the 2020 Nobel Prize in chemistry for codeveloping the CRISPR-Cas9 gene editing technique.

## KEY INSIGHT

**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.**

## EXAMPLES

Last year, Jennifer Doudna, a biochemist at the University of California, Berkeley, and Emmanuelle Charpentier, director of the Max Planck Unit for the Science of Pathogens, won the 2020 Nobel Prize in chemistry for the codevelopment of CRISPR-Cas9. Human trials will test CRISPR's potential to treat numerous genetic diseases, including congenital blindness, muscular dystrophy, Alzheimer's disease, and sickle cell anemia.

## DISRUPTIVE IMPACT

Scientists hope CRISPR will help boost our immune systems, whether it's fighting off tumor cells with fewer side effects than chemotherapy or entirely disabling cancer cells themselves. Expect widespread clinical use of the technology this decade.

## EMERGING PLAYERS

- Mammoth Biosciences
- Verve Therapeutics
- Plantedit
- Caribou Biosciences
- Vertex Pharmaceuticals



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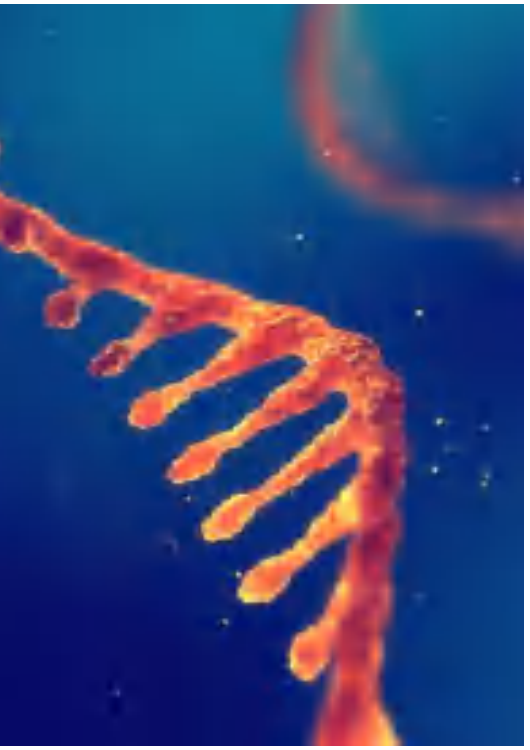
1ST YEAR ON THE LIST

# mRNA Vaccines



Vaccines with messenger RNA are quick to design and test.

## KEY INSIGHT

**As genetic material that contains instructions for making proteins, messenger RNA is revolutionizing vaccine development.**

## EXAMPLES

Last year marked the first time a marketed drug used mRNA vaccines. 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 overwrite the code in our cells. This breakthrough technology falls under the umbrella of synthetic biology. Researchers believe that sending new instructions into our cells could help protect us against a number of viruses in the very near future. An mRNA vaccine to fully immunize people against malaria is in the works.

## DISRUPTIVE IMPACT

Researchers can design and test mRNA vaccines more quickly than traditional ones. This new biotechnology can be manufactured synthetically, rather than through cultured cell lines or other living cells such as chicken eggs (a common human allergen). Synthetic biology systems can automate the design-test-build sequence for rapid learning, targeting variants and making adjustments as needed.

## EMERGING PLAYERS

- BioNTech
- Moderna
- Bill & Melinda Gates Foundation
- U.S. National Institutes of Health
- Intellia Therapeutics



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## Perpetual Puppies

**Mid-future pessimistic scenario**

Advances in synthetic age reversal find an off-brand use: our pets. Not only do we rush to keep the pets we love alive for longer, but some are never even allowed to age. Socialites biohack puppies and kittens to keep them purse-sized, preventing them from physically maturing. Even though these pets look adorable, their biology resists the changes we make, leading to complications and in some cases shortening their lifespans instead of extending them. The constant tension between keeping them young and keeping them alive is a biological balancing act that torments the animals and leaves them in a near-catatonic state. Animal rights activists push back, but with no regulation and few enforceable nonhuman rights, perpetually young pets perpetually suffer.

# Scenarios



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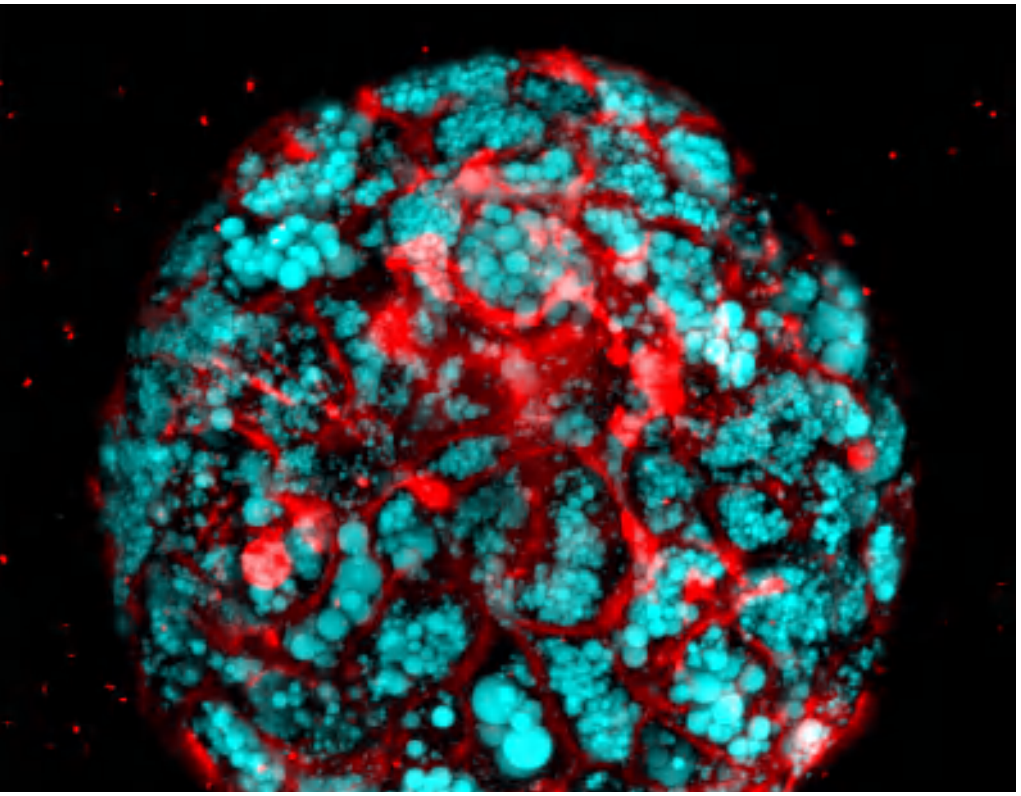
# Synthetic Biology and Biotech Trends



**A tiny bioengineered human liver organoid grows in the lab with pluripotent stem cells.**
Image credit: Cincinnati Children's Hospital.

## Single-Nucleotide Polymorphism (SNP) Profiling

Researchers are developing a new technique that might someday enable people to upgrade their children before birth. Think of an SNP as a single genetic letter (A, T, C, G). Tinkering with the order of those letters could optimize human genetic code for the best possible outcomes. This doesn't mean creating babies with a certain hair or eye color but rather lowering the odds of future heart disease or perhaps acquiring diabetes. The procedure requires in vitro fertilization for now: Embryos can be SNP-profiled, and the best possible combination would be used for the pregnancy. Future generations would pass those traits forward.

## 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, raising ethical concerns. 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.

## Assembloids

Miniature snippets of the nervous system are being used to create miniature blobs of brain tissue. When put together, lab-grown muscles and brains can establish neural highways and process information. Researchers at Stanford University are experimenting with self-assembling tissue that responds to stimuli. In one instance, the tissue twitched on command.

## Organoids for COVID-19 Research

Lab-grown lung and brain tissues are being used to research the lasting effects of SARS-CoV-2, the virus that causes COVID-19. Miniature guts and livers are also being grown in high-security labs and infected with the virus, as are combinations of different organs (called a "body on a chip").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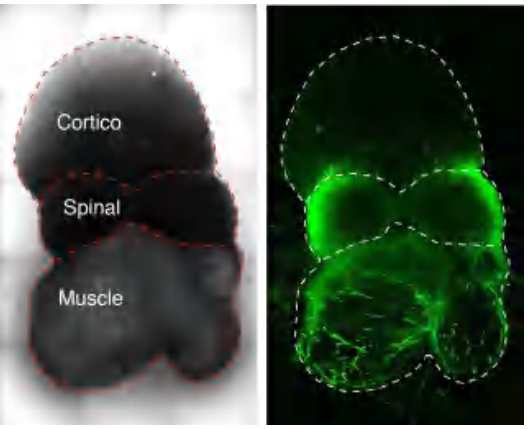
# Synthetic Biology and Biotech Trends




**Researchers assembled a working model of a human brain-to-muscle nerve circuit in a dish.**
Image credit: Jimena Andersen/Pasca Lab.

## Super-Fast Molecule Discovery

Scientists now use synthetic biology to discover and produce molecules on demand. The Defense Advanced Research Project Agency and the MIT-Broad Institute Foundry tested whether new molecules could be generated for practical use. By combining artificial intelligence and synthetic biology, the team delivered six out of the 10 requested designer molecules in just 90 days.

## DNA Storage

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. To date, scientists have stored a $50 Amazon gift card, an operating system, and a film, "L'arrivée d'un train en gare de La Ciotat," a black-and-white French short from 1896. Last year, Chinese scientists at Tianjin University stored 445KB of data in an E. coli cell. 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. Twist Bioscience, a DNA storage startup, discovered how to make hyper-dense, stable, affordable DNA storage. By depositing microscopic drops of nucleotides onto silicon chips, Twist's robots can create a million short 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.

## Computational Biology Advancements

Proteins are essential to life. These large, complex molecules contain chains of amino acids and come in unique shapes. A protein's structure determines its job, whether it's transporting oxygen or protecting the body from pathogens. Researchers at DeepMind developed an AI system to understand protein structures. Called AlphaFold, it accurately predicts the shape of a protein from its amino acid sequence. This discovery will accelerate research, giving scientists more precise information about how proteins function inside cells.

## Engineered Mosquitoes

This year, millions of genetically engineered mosquitoes will be released in the Florida Keys. The Florida Keys Mosquito Control District Board of Commissioners approved a pilot project to introduce male mosquitoes that have been engineered to pass on a gene making it difficult for their offspring to reproduce. Male mosquitoes don't bite, and the U.S. Environmental Protection Agency says they pose no human threat. 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.

## Genetically Modified Cephalopods

Last year, scientists created the first genetically modified squid using CRISPR. Research on cephalopods is particularly important because squids are highly intelligent, have complex nervous systems, and communicate using sophisticated signals that scientists don't understand. Researchers could use gene editing to study and learn more about cephalopod brains. At the Massachusetts-based Marine Biological Laboratory, researchers successfully mapped a squid genome and edited embryos to create a transparent creature. (Typically, this variety of squid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# Synthetic Biology and Biotech Trends

has dark spots.) Because cephalopods are so intelligent, research is highly regulated in the European Union and in Canada, but there are fewer protections in the U.S. As scientists begin editing the genetic code of squid and other sea life, they must consider the ethical implications.

## Designer Cells

Researchers have already developed artificial cells that come very close to the real thing. But last year, University of California, San Diego, scientists discovered a technique to create 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.

## Molecular Robotics

Molecular robotics will someday be used on all life forms to provide targeted therapies as well as genetic augmentation. Scientists at the Wyss Institute for Biologically Inspired Engineering at Harvard University 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 University 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. In 2018, 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.

## Cloning and Synthesizing Viruses

Early in the global pandemic, a team at the University of Bern 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.

## 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 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 the yeast to develop milk proteins, which they combine 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

Last summer, the U.S. prepared for a new school year with no Covid vaccine in sight, and a group of citizen scientists


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# Synthetic Biology and Biotech Trends

Researchers hope that engineered Aedes aegypti mosquitoes will reduce the total population in Florida.

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 an open-science approach. 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 independently. 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.

## 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 own 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 a $299 test that returns a complete genetic code. Ancestry.com and 23andMe offer genotyping tests, which look only at a part of the genome, for $99 to $199.

## Gattaca Baby Tests

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 now 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.

## Artificial Human Genomes

Researchers at the University of Tartu, Estonia, use neural networks to develop novel segments on human genomes. Because genetic data is sensitive, the hope



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# Synthetic Biology and Biotech Trends

is that an artificial human genome will allow researchers to study DNA without infringing on anyone's privacy.

### Genetic Research's Bias Problem

Less than 2% of people who have had their genomes sequenced are from Africa. Overwhelmingly, the majority of 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.

### Creating 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 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.

### Gene Vandalism

Sometimes the gene editing process results in breaking the double strands of a DNA's helix. That results in what synthetic biologist George Church calls "gene vandalism." As cells try to repair the break, it often results in unintended modifications and mutations that cannot be easily controlled and could be dangerous. Gene vandalism is on the rise as more researchers experiment with CRISPR.

### Prime Editing

A new 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.

### Synthetic Age Reversal

The source code for humanity is stored in our DNA. As we age, the sequence might stay constant, but there are chemical changes that 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, George Church and a team at Harvard's Wyss Institute combined 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.

### Superbugs

Months before the pandemic, researchers at Johns Hopkins University ran a simulation of a hypothetical, treatment-resistant coronavirus outbreak spawned at a Brazillian pig farm. In the simulation, 65 million people died in just 18 months. When SARS-CoV-2 became a global pandemic last year, it joined a host of superbugs already rampant elsewhere in the world. Each of them holds potential for massive spread, and yet despite these hypothetical risks, most governments underspend on emerging disease research.

### Building Full Chromosomes

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. But now there's a new initiative: the Human Genome Project-write (HGP-write). This is a synthetic biology initiative, and it's a grand-scale collaboration to synthesize new species of microbes, plants, and animals.

### 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 and improve, our storage needs will explode, along with the computing power and requirements for acquiring, distributing,


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# Synthetic Biology and Biotech Trends

**The longfin inshore squid on the left is unmodified, with its original red dots visible. The right was edited using CRISPR-Cas9 to make it completely translucent.**

Image credit: Karen Crawford.

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 in the future.

## China's Genetically Edited Babies

In 2015, Chinese researchers edited the genes of a human embryo. 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 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. In December 2019, Chinese state media revealed that He's work had resulted in additional births beyond the twins. Authorities arrested him and sentenced him to three years in prison for "illegal medical practices."

## Super Pigs

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 breads 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.

## De-Extincting Animals

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



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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.

## 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.

## Microbiome Extinction

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. Startup uBiome has launched several at-home microbiome tests—although currently a subscription is required for a test. The American Gut Project, the American Gastroenterological Association, and OpenBiome will track 4,000 patients over 10 years to learn about fecal microbiomes. Investors have poured more than $1 billion into microbiome startups since 2016.

## Building a Comprehensive Human Cell Atlas

Researchers are building the first-ever comprehensive map of all 37.2 trillion human cells in the body. A large team of scientists—including 130 software engineers, mathematicians, computational scientists, biologists, clinicians, and physicists hailing from Israel, the Netherlands, Japan, the UK, the U.S., and Sweden—are mapping the human body on a cellular level. 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 a comprehensive reference map for all human cells in the body will give the medical community a new way of understanding how our bodies work and will help diagnose, monitor, and treat disease.

## The Post-Natural Age

In the 20th century, biologists focused on taking things apart—things such as tissues, cells, and proteins—to learn how they function. This century, synthetic biologists are focusing on intentional design—improving organisms or constructing new materials from life's building blocks. 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.


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# Agriculture

6TH YEAR ON THE LIST

# AgTech

Emerging technologies will transform agriculture.

## KEY INSIGHT

**By 2050, we must increase agriculture production by 70% to meet projected global demand for food. Traditional farming methods won't cut it. That shortfall has spawned a new generation of agriculture technology startups. Dozens of startup accelerators have popped up, and big tech firms such as Microsoft and Amazon have built new businesses to support high-tech farms.**

## EXAMPLES

If you're a human who eats food, you should care deeply about the global food supply. With our global weather patterns and climates in flux, it's plausible that the world's current agricultural centers won't sustain commercial farms in the near future. Today's agriculture system alone won't work. The availability of sensors, new types of irrigation, improved lighting, and more efficient ways to capture and process data promise to modernize and decentralize the agricultural sector.

## DISRUPTIVE IMPACT

Our existing global food system is a significant driver of climate change. The food system is also vulnerable to climate change's effects. We're facing a long-term existential risk in the global food supply, but we're also seeing tremendous new research and opportunity in agtech.

## EMERGING PLAYERS

- Azure FarmBeats
- John Deere
- Plantix
- Higher Steaks
- Artemys Foods
- Earthpac
- Infarm



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# AgTech Trends

Microsoft's FarmBeats brings AI to farmers around the world.

## 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 smarter decisions.

## 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 by Abundant Robotics and 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.

## 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.

## Vertical Farming Grows Up

Amazon's Jeff Bezos and SoftBank's CEO Masayoshi Son (until April 2021) have both invested in vertical farming, a burgeoning industry in which crops are grown in stacked layers inside of climate-controlled environments. In the past, the expense of robots, artificial light, and other equipment made ver-



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# AgTech Trends

In Japan, vertical indoor farming is becoming more widespread.

tical 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.

## Indoor Plant Factories

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 Kameoka, 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.

## 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.

## CRISPR Crops

The gene-editing tool CRISPR promises to enhance the nutritional value of produce, increase crop yields, and extend freshness. CRISPR 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.)

## Cellular 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. Memphis Meats, 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." In 2018, the U.S. beef industry filed a petition to bar nonanimal products from the definition of meat. Plant-based meat sales have eclipsed $1 billion annually. In the future, you may buy meat at a local microbrewery that "brews" meat instead of beer.



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# AgTech Trends

## 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. This year, KFC will begin selling hybrid chicken nuggets, made of 20% cultured chicken cells and 80% plants. 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 yogurt, cheese, and ice cream.

## 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 environmentalist 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.

## Intelligent Packaging

Smart packaging will drive agricultural advances and investment. The nascent market is growing and includes such tech as QR codes for moisture-control and temperature sensors, antimicrobial and edible packaging, and packaging that "eats" itself after it is no longer needed. 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.

## Artificial Trees

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.

## Off-Planet 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 (see: Space and Off-Planet Trends), 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.


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## Emailing Apples to Space

**Far-future optimistic scenario**

The first colonists to arrive on Mars bring a mixed payload of seedlings, mature plants, and special printers designed to extrude DNA from code. A team of expat astrobiologists and engineers collaborate with researchers back on Earth to test off-planet terraforming. Just like in the early days of the world wide web, when disparate groups of academics sent data around the world using a nascent internet, these researchers use an interplanetary communications system to send and retrieve biological data. Rather than sending an apple tree to space, Earthers send the DNA to new Martians for tweaking and printing. Exotic Martian agriculture is sent back to Earth for experimentation and enjoyment.

# Scenarios



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> Mars had been a colony for a long time, and it was filled with the best scientists and technologists humanity had to offer. We were ready to govern ourselves and start a new nation of our own, but everything we built, or mined, or made, was still the property of old mother Earth.
>
> — Solomon Epstein in *The Expanse*

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# Application

## STRATEGY

The intersection of technology, agriculture, and biotech impacts every business, because ultimately these trends influence the future of life. Chief strategy officers should begin to plan for next-order changes on the horizon. Improved packaging will make the cold chain less energy hungry and easier to manage, while universal vaccines will result in employees who get sick less often. First movers and fast followers could help shape the directions of their industries, which would be a long-term strategic advantage.

## INNOVATION

Bioluminescence could provide artificial light sources, and agriculture clouds will lead to hyper-productive farms. Chief innovation officers have a world of opportunity ahead. Innovation teams should begin developing new uses, models, and products that will soon unlock new consumer demand spaces.

## R & D

Biotech R&D has plenty of interest, thanks to the groundbreaking success of mRNA Covid vaccines and the 2020 Nobel Prize awarded to the scientists behind CRISPR. Investors express enthusiasm about the possibilities of these technologies, but they aren't always patient. R&D teams should work to convince executives and boards that the next few years will require research—and product development will follow.

## RISK

Each of these trends poses clear risks of dual-use technologies. While CRISPR promises to revolutionize health care, it can also be weaponized. Chief risk officers must carefully consider the downstream impacts of using new biotechnologies. An even thornier risk on the horizon: If a new technology promises to address a major issue, such as climate change, and your company does not embrace it, could your organization face future lawsuits or regulatory actions?



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# 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 about synthetic biology, genetic editing, and agricultural technologies:

1

In what ways will advances in synthetic biology improve our supply chain?

Our manufacturing processes? Our product lines?

2

What parts of our business make us vulnerable to ethical challenges?

3

Are we adequately planning for the longer term?

What assumptions must hold true for our current strategy to succeed?

How will we make needed changes?



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