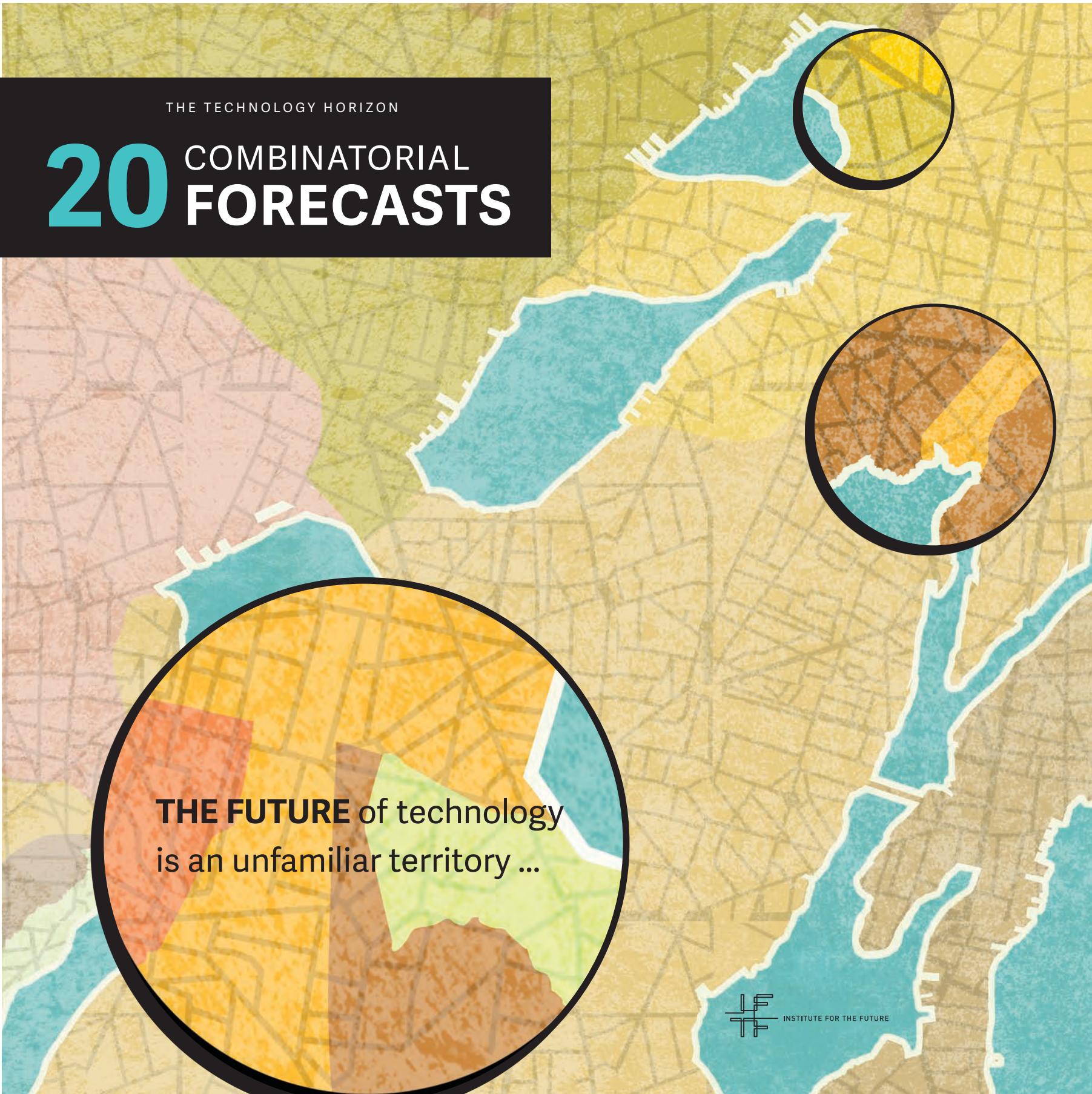


THE TECHNOLOGY HORIZON

20 COMBINATORIAL FORECASTS



THE FUTURE of technology
is an unfamiliar territory ...

IN THE NEXT DECADE, we will advance into a number of new technology territories. In many cases, the outlines of these new frontiers are already becoming visible on the horizon, as small-scale discoveries, innovations, and experiments hint at things to come.

For more than thirty years, IFTF's Technology Horizons Program has been scouting ahead, exploring these emerging technology spaces.

Each year, IFTF creates forecasts and maps charting the technology horizon for the next decade—pointing out both technological shifts and transformations. In 2014, we continue this process by taking a broad look ahead at the amazing technological innovations and disruptions emerging from the intersection of future possibilities.

Against a background of accelerating change, dynamic social reconfigurations, and rapid organizational innovation, we have revisited the processes we use to build foresight. Linear extrapolation of technological trends is insufficient. Technological change is increasingly driven by the combination and recombination of foundational elements. Over the next decade, many different foundational technologies will get mixed and remixed in new and different combinations. Combinatorial forecasting embraces this complexity to anticipate the future emerging at these intersection points.

This Technology Horizon map presents twenty new innovative combinatorial forecasts you can use to navigate the future as it unfolds. Each combinatorial forecast is built on a range of enabling technologies and newly opening possibilities. Concrete examples from the world today, including emerging technologies, new research, innovative businesses, or other endeavors, demonstrate the direction of the forecast as a whole.

This map is just one view of the technology landscape that lies before us. Think about it as a work in progress. We hope that you consider it an invitation to add your own landmarks and fill in unexplored regions.

20 COMBINATORIAL FORECASTS: FRONTIERS OF INNOVATION

1 The microbiome mediates the war on germs

LIFE SCIENCE SUBSTANCES

Increased understanding of the microbiome—the community of microorganisms in our bodies—is challenging our long-running obsession with antibacterial measures. New approaches to staying healthy will be based on balancing the ecologies of microorganisms: think “bugs, not drugs.” Indiegogo-funded uBiome is already helping people better understand their germs by sequencing the bacteria in their bodies.

SO WHAT? This new understanding will likely lead to a new wave of probiotic products and perhaps even to seeding babies’ guts with microbial life.

2 Thinking and feeling become quantifiable

LIFE SCIENCE PERSONAL EXPERIENCE

Sophisticated brain-imaging technologies and neural modeling using machine-learning algorithms are promising to enable measurement of subjective aspects of human experience. Neuroscientists can read visual images from brain activity. Assigning precise measurements to feelings like pain through neurofeedback and other techniques could allow for comparison, modulation, and manipulation of these feelings.

SO WHAT? Direct measurement of our once-private thoughts and feelings can help us understand other people's experience but will also present challenges regarding privacy and definition of norms.

3 Biomanufacturing unites mother nature with the man-made

LIFE SCIENCE SUBSTANCES INDUSTRY

As the recent public debut of lab-grown meat hints, bioengineering technologies are transforming manufacturing. With biomanufacturing, heretofore associated with the development of pharmaceuticals and artificial organisms, new biology-based processes will do things that only machines have previously done. For example, scientists have recently been able to modify cells to act like fully functional computers.

SO WHAT? People and organizations involved in manufacturing and production will face new competitive dynamics from bio-inspired processes and designs.



4 The cloud coalesces into a global supercomputer

DISTRIBUTED COMPUTATION INFORMATION NETWORKS NETWORKED MATTER

No longer simply a way to virtualize enterprise IT or to expand storage capacity, cloud computing offers a more disruptive capability. It lends greatly expanded processing power to any computational project, from personal analytics on your smartphone to enterprise simulations for the firm. Moreover, as powerful computation becomes ever more embedded in everyday objects, the internet of things will also run on this cloud supercomputing network.

SO WHAT? As access to cheap, scalable supercomputing in the cloud becomes available to any device or app whenever, wherever, it will be put to new uses as a problem-solving tool even in geographies with resource constraints.

5 Reality will be in the eye of the beholder

PERSONAL EXPERIENCE CULTURE AND SOCIETY

While technology has traditionally served to connect us in a shared reality, wearable and embedded devices will increasingly allow for our fundamental perceptions to radically diverge. The coming generations of augmented reality and brain-computer interfaces will shape our views according to highly personalized filters. Ultimately, this could create a world where each individual lives in his or her own digitally layered reality.

SO WHAT? Polarization and miscommunication will increase as shared context becomes scarcer, while people and organizations that can clearly communicate across perceptual layers will gain value.

6 We'll all see through other people's eyes

PERSONAL EXPERIENCE CULTURE AND SOCIETY INFORMATION NETWORKS

Virtualization and wearable computing devices will combine to create a new wave of social technology. The Oculus Rift, a virtual reality headset for 3D gaming, already allows users to virtually explore real environments from the perspective of a child, and wearable recording devices are beginning to capture the details of everyday life.

SO WHAT? While offering the possibility of amplifying compassion, this new technology also raises privacy issues and creates nearly endless marketing and customization opportunities for enterprises.

7 Intelligence moves to the networked edges

INFORMATION NETWORKS DISTRIBUTED COMPUTATION

Network processing power is concentrated today at the core (in the cloud) and on the periphery (in end-point devices), but we will see increasing intelligence at intermediate processing points. New “hotspots of smart” in our communications network infrastructure will facilitate seamless local interactions between diverse networked people and things.

SO WHAT? Geography matters in localized processing. Physical spaces with access to intermediate processing can be made smarter than those with access only to traditional networks.

8 Work becomes programmable

CULTURE AND SOCIETY INFORMATION NETWORKS

Early Internet technologies allowed a freer, more open way of communicating. That transformation naturally led to a revolution involving commerce. We are on the brink of the next Internet revolution: coordination. Start-ups and technologies will rush to map and activate spare capacities and resources—from human skills to legacy assets—in massively coordinated efforts.

SO WHAT? A striking variety of approaches to coordinating everything from resource sharing to complex workflows will upend twentieth-century models of commerce, work, learning, and productivity.

9 Code becomes law

CULTURE AND SOCIETY

With sensors and programmable devices everywhere, law enforcement will become embedded in the environment. It might soon be impossible for people or machines to do illegal things, a scenario that many enforcement agents prefer. For example, the EU has proposed that cars be designed so that they cannot exceed about 70 mph.

SO WHAT? Governance is shifting from reliance on individual responsibility and human policing toward a system of embedded protocols and automatic rule enforcement.

10 Graphene supermaterials spark a nanorevolution

RESOURCES SUBSTANCES

Improvements in the production of graphene (a two-dimensional material consisting of a nanoscale honeycomb lattice made of carbon atoms) are laying the groundwork for vastly more effective energy systems, faster chip architectures, stronger plastics, more accurate sensors, and batteries that last. Manufacturing challenges still exist, but teams of researchers at Stanford, MIT, and Harvard have found methods using DNA to scaffold the construction of molecularly perfect graphene structures.

SO WHAT? Graphene supermaterials have the potential to revolutionize materials science, creating artifacts that can do seemingly magical things.

11 Magical materials transform digital devices

RESOURCES

Supermaterials currently under development will transform consumer electronics as we know them. Memristors, for example, will soon allow designers to create devices with memory systems that function more like a brain. Further out, energy-efficient technologies and supercapacitors could dramatically improve battery performance.

SO WHAT? We have become used to basic limitations in the way electronics work, but many future electronic systems will be limited only by our own imaginations.

12 Waste mining pushes against planned obsolescence

SUBSTANCES RESOURCES LOGISTICS INDUSTRY

Waste materials will become increasingly valuable as new technologies offer better ways to extract reusable substances like rare metals from discarded products. Global energy demands will revitalize the waste and recycling industries. Already, industrial-scale systems are under construction by companies such as Enerkem in cities worldwide to convert nearly all local landfill waste to energy.

SO WHAT? Traditional landfills will be our mines of the future as new standards, incentives, and technologies emerge to prolong the life cycle of materials and supplies.

13 The new space race yields innovations on Earth

RESOURCES LOGISTICS

With efforts under way to commercialize spaceflight, governmental organizations will become customers of entrepreneurial ventures around medicine, manufacturing, and surveillance funded by private industry. This decade's space race will be between companies like SpaceX jockeying for NASA contracts, third parties such as biotech firms seeking to do microgravity medical research, and private outfits like Virgin Galactic cashing in on a boom in space tourism.

SO WHAT? The first space race drove breakthroughs in science and technology that eventually trickled down to civilians. This one, springing directly from the private sector, will likely accelerate R&D and commercialization of new technologies developed for, or in, space.

14 Matter routing delivers a new kind of supply web

NEW COMPETITION NETWORKED MATTER LOGISTICS DATA

Rapid innovation in mobile commerce, autonomous vehicles, detailed urban traffic models, and routing algorithms will begin to string together end-to-end solutions to route actual things where and when they are needed. Google's autonomous car project and early experiments with drone-based delivery services will finally be commercially deployed.

SO WHAT? Supply chains will become far more complex supply webs, and people will be able to access things in real time through many more channels.

15 The human-machine division of labor rebalances

NETWORKED MATTER LOGISTICS DATA

On the factory floor, humans will learn to work alongside robot colleagues that augment and extend human capabilities. Already, BMW is testing “collaborative robots” in its factories that, for example, glue parts together that are held in place by more precise human fingers. Kiva Systems is automating the warehouse floor with robots increasing human productivity. And “social robots” are aiding health-care workers and caregivers in homes and hospitals.

SO WHAT? We'll rethink what it means to be human in a world remade for machines and embrace the opportunity to do what we're uniquely good at while leaving the rest for the machines.

16 Local energy production will power the smart grid

RESOURCES LOGISTICS

As the smart grid begins to take shape, a big push is emerging for more localized energy production. The idea is to deploy cheaper and more climate-friendly solar, wind, and fuel cell technology at the neighborhood scale, with smart routing and storage. Watch for widespread decentralization of energy grids as digital intelligence and renewable energy technologies drive power production to the edges of our networks.

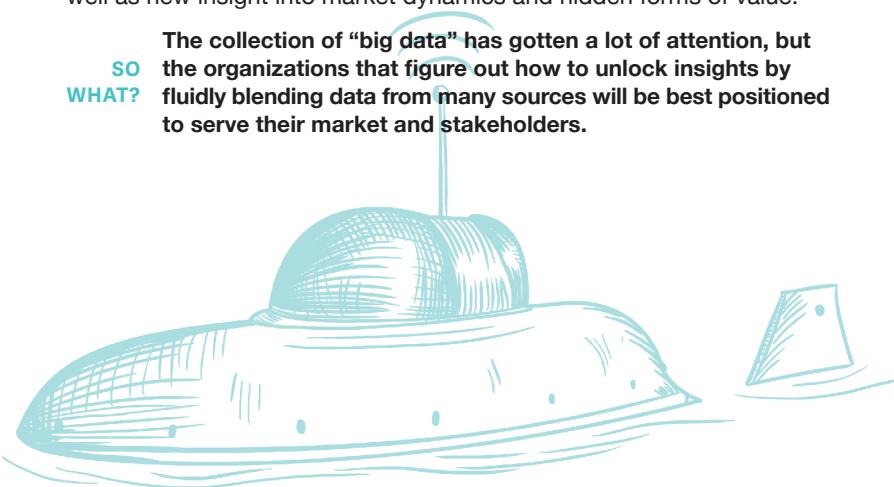
SO WHAT? Complicating the debate about sprawl and land use, this shift could mean that—as at least one study argues—suburbs are the most sustainable use of land for distributed solar.

17 The data race shifts gears from information to insights

NETWORKED MATTER DATA

As sensing and computing become available all the time everywhere, organizations that can create machine intelligence tools and operating practices to blend massive amounts of data from many sources will move to the forefront of innovation. They will have a competitive advantage through amplified decision support and complex task management as well as new insight into market dynamics and hidden forms of value.

SO WHAT? The collection of “big data” has gotten a lot of attention, but the organizations that figure out how to unlock insights by fluidly blending data from many sources will be best positioned to serve their market and stakeholders.



18 The Internet becomes a network of networks

NETWORKED MATTER DISTRIBUTED COMPUTATION ARTIFICIAL INTELLIGENCE NEW COMPETITION

Over the coming decade, we will see more specialized networks established as an alternative to the Internet as we know it. For example, the emergence of services built into the hardware layer of new network topologies shows promise. This arrangement could dramatically reduce downtime and lead to new smart grids, inexpensive but high-quality video conferencing, and faster financial transactions and swarm computing clusters. Since existing Internet infrastructures will limit many of these possibilities, we will likely see additional fragmentation through tailor-made sub-networks. Your experience of the Internet will fragment too as entirely new Internets—from finances to health—emerge to leverage flexibility, efficiency, and security gained in new network arrangements.

SO WHAT? Matching more specialized networks to specific applications will be a functional challenge for organizations, individuals, and network providers. There will be no single Internet but many Internets.

19 Machines get a social life

DISTRIBUTED COMPUTATION ARTIFICIAL INTELLIGENCE

Computation will continue to move away from single-user desktop applications and toward a rich variety of novel forms and architectures. Ultimately, as machine-to-machine systems mature, these digital systems will interact with each other far more than with human users and will cooperate in new ways. MIT researcher David Rose frames this shift as a transition from traditional computation toward a world of “enchanted objects.”

SO WHAT? To a large extent, new computation technologies will revolve around finding ways for computers to connect and communicate with each other without people getting in the way.

20 An algorithm arms race risks a Sorcerer's Apprentice scenario

ARTIFICIAL INTELLIGENCE NEW COMPETITION

As prediction algorithms are deployed to detect geopolitical and financial discontinuities, they will increasingly be designed to anticipate and outdo one another. Once these bots are empowered to act upon and adjust our increasingly critical connected systems—such as global markets, smart cities, and social networks, competing programs could create chaos. Financial trading algorithms, for example, have already been implicated as the cause of market “flash crashes.”

SO WHAT? Chaos caused by competing algorithms could thwart our ultimate goal of fine-tuning systems to avoid potential problems.

20 COMBINATORIAL FORECASTS

FRONTIERS OF INNOVATION

The future of technology is an unfamiliar territory. The landscape of technologies on this map reveals a territory shaped by new combinations of foundational elements. Look out for transformations in this landscape as technology mashups generate unprecedented opportunities for disruption.

This technology horizon map is designed to help you anticipate the future of combinatorial innovations emerging at the intersection of distinct territories. It is therefore important to understand that multiple territories shape each forecast. Understanding what these territories look like in the coming decade requires us to focus in on the intersections where territories blur and the future emerges.

Use the map to visualize the whole range of innovations and see the bigger picture—a more interconnected technology landscape.

- **CONSIDER** the other forecasts nearby as you read through each forecast.
- **DEVELOP** your own insights about how forecasts impact each other.
- **ANTICIPATE** the future by identifying which territories on the map are most transformative or disruptive to your future.

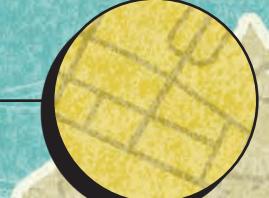
This map is organized around **20 combinatorial forecasts**. These are the big stories, the hot spots that will shape the landscape of technology in the coming decade. Each combinatorial forecast emerges from the intersection of multiple territories.

 15 The human-machine division of labor rebalances

13 territories, or frontiers of innovation, define the landscape of the map. Each forecast shares common ground and takes place at the intersection of up to 4 territories.



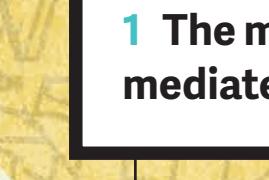
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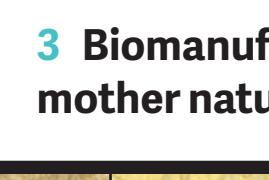
 11 Magical materials transform digital devices

LIFE SCIENCE

Modifications in our approaches to genetics, organisms, biomaterials, and ecology

 2 Thinking and feeling become quantifiable

 1 The microbiome mediates the war on germs

 3 Biomanufacturing unites mother nature with the man-made

SUBSTANCES

Advances in materials science, engineering, and physical processes

INDUSTRY

Upheavals in manufacturing and production processes

 12 Waste mining pushes against planned obsolescence

 13 The new space race yields innovations on Earth

RESOURCES

Changes in the availability and use of raw materials

 14 Matter routing delivers a new kind of supply web

 15 The human-machine division of labor rebalances

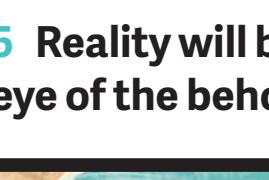
LOGISTICS

Evolutions in the physical transportation and coordination of people and things

PERSONAL EXPERIENCE

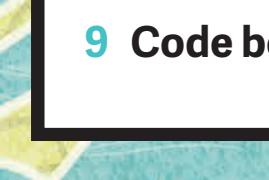
Developments impacting the ways that we perceive and interface with the world

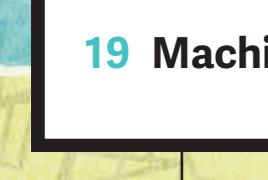
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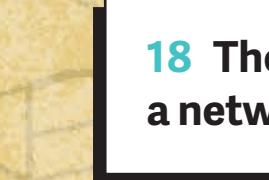
 5 Reality will be in the eye of the beholder

 6 We'll all see through other people's eyes

 8 Work becomes programmable

 9 Code becomes law

 19 Machines get a social life

 18 The Internet becomes a network of networks

 17 The data race shifts gears from information to insights

 20 An algorithm arms race risks a Sorcerer's Apprentice scenario

CULTURE AND SOCIETY

Shifts that affect our connections to other individuals and groups

 20 An algorithm arms race risks a Sorcerer's Apprentice scenario

INFORMATION NETWORKS

Refinements in the structure of the Internet and the web of digital links around us

DISTRIBUTED COMPUTATION

New ways that digital processing is being used and organized

ARTIFICIAL INTELLIGENCE

Frontiers in software and machine cognition

DATA

New applications for facts and statistics being collected by smart systems

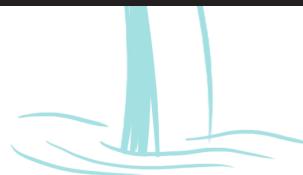
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THE TECHNOLOGY HORIZON 2014-2024



ABOUT THE INSTITUTE FOR THE FUTURE

The Institute for the Future is an independent, nonprofit strategic research group with more than 45 years of forecasting experience. The core of our work is identifying emerging trends and discontinuities that will transform global society and the global marketplace. We provide our members with insights into business strategy, design process, innovation, and social dilemmas. Our research generates the foresight needed to create insights that lead to action. Our research spans a broad territory of deeply transformative trends, from health and health care to technology, the workplace, and human identity. The Institute for the Future is based in Palo Alto, CA.

ABOUT THE TECHNOLOGY HORIZONS PROGRAM

The Technology Horizons Program combines a deep understanding of technology and societal forces to identify and evaluate discontinuities and innovations in the next three to ten years. We help organizations and communities develop insights and strategic tools to better position them for the future. Our approach to technology forecasting is unique—we put people at the center of our forecasts. Understanding humans as consumers, workers, householders, and citizens allows IFTF to look beyond the technical capabilities and identify the value in new technologies, forecast adoption and diffusion patterns, and discover new market opportunities and threats, as well as anticipate how we will live, work, and connect with one another in the coming decade.

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