STANFORD UNIVERSITY

THE STANFORD EMERGING TECHNOLOGY REVIEW 2026

A Report on Ten Key Technologies and Their Policy Implications

CO-CHAIRS Condoleezza Rice, Jennifer Widom, and Amy Zegart

DIRECTOR AND EDITOR IN CHIEF Herbert S. Lin | **MANAGING EDITOR** Martin Giles

EXECUTIVE SUMMARY

Emerging technologies have never been more important or difficult to understand. Breakthrough advances seem to be everywhere, from ChatGPT to the COVID-19 mRNA vaccines to constellations of cheap commercial shoebox-size satellites that can track events on Earth in near-real time. This is a pivotal technological moment offering both tremendous promise and unprecedented challenges. Policymakers need better expert resources to help them understand the burgeoning and complex array of technological developments—more easily and more continuously.

The *Stanford Emerging Technology Review* (*SETR*) is designed to meet this need, offering an easy-to-use reference tool that harnesses the expertise of Stanford University's leading science and engineering faculty in ten major technological areas.

***SETR* 2026 FOCUS TECHNOLOGIES**

Artificial Intelligence
Biotechnology and Synthetic Biology
Cryptography and Computer Security
Energy Technologies
Materials Science
Neuroscience
Quantum Technologies
Robotics
Semiconductors
Space

These particular fields were chosen for this report because they leverage areas of deep expertise at Stanford and cover many critical and emerging technologies identified by the Office of Science and Technology Policy in the White House and by other US government departments. However, *SETR* focus technologies are likely to change over time. This is not because we were incorrect but because science and technology never sleep, the borders between fields are porous, and different people categorize similar research in different ways.

Report Design

This report is organized principally by technology, with each area covered in a stand-alone chapter that gives an overview of the field, highlights key developments, offers an over-the-horizon view of important technological issues, and reviews key policy considerations. Although these chapters can be read individually, one of the most important and unusual hallmarks of this moment is convergence: Emerging technologies are intersecting and interacting in a host of ways, with important implications for policy. We examine these broader dynamics in chapters 11 and 12. In chapter 11, we describe a number of themes and commonalities that cut across many of the technologies we describe earlier in the report. In chapter 12, we consolidate technological developments across all ten areas and discuss how they apply to five policy domains: economic growth, national security, environmental and energy sustainability, health and medicine, and civil society.

Three tensions run throughout and are worth keeping in mind:

- **Timeliness and timelessness** Each chapter seeks to strike a balance between covering recent developments in science and the headlines, and providing essential knowledge about how a field works, what is important within it, and what challenges lie ahead.

- **Technical depth and breadth** This report intentionally skews toward breadth, offering a thirty-thousand-foot view of a vast technological landscape in one compendium. Readers should consider it an introductory course. Other products and educational tools released in the future will offer additional insights into each field.

- **Technical and nontechnical aspects of innovation** We start with the science but do not end with the science. Technological breakthroughs are necessary but not sufficient conditions for successful innovation. Economic, political, and societal factors play enormous and often hidden roles. Johannes Gutenberg invented the printing press in 1452, but it took more than 150 years before the Dutch invented the first successful newspapers. This was not because they perfected the mechanics of movable type but because they decided to use less paper, making newspapers sustainably profitable for the first time. Each chapter in this report was written with an eye toward highlighting important economic, political, policy, legal, and societal factors likely to impede, shape, or accelerate progress.

Technologies and Takeaways at a Glance

Artificial Intelligence

Artificial intelligence (AI) is a computer's ability to perform some of the functions associated with the human brain, including perceiving, reasoning, learning, interacting, problem-solving, and even exercising creativity. In the past year, some of the main AI-related headlines focused on the rapid evolution of the field, including in areas such as large language models and multimodal models integrating vision and language, and on AI's growing adoption by both good and bad actors in society.

KEY CHAPTER TAKEAWAYS

- AI is a foundational technology that is supercharging other scientific fields and, like electricity and the internet, has the potential to transform societies, economies, and politics worldwide.

- Despite rapid progress in the past several years, even the most advanced AI models still have many failure modes and vulnerabilities to cyberattacks that are unpredictable, not widely appreciated nor easily fixed, and capable of leading to unintended consequences.

- Nations are competing to shape the global rules and standards for AI, making interoperability, sizeable national compute resources, and international governance frameworks critical levers of geopolitical influence.

Biotechnology and Synthetic Biology

Biotechnology is the use of cellular and biomolecular processes to develop products or services. Synthetic biology is a subset of biotechnology that involves using engineering tools to modify or create biological functions—like creating a bacterium that can glow in the presence of explosives. Synthetic biology is what created the COVID-19 mRNA vaccine in record time (although the effort relied on decades of earlier research). Just as rockets enabled humans to overcome the constraints of gravity to explore the universe, synthetic biology is enabling humans to overcome the constraints of lineage to develop new living organisms.

KEY CHAPTER TAKEAWAYS

- Biotechnology is emerging as a general-purpose technology by which anything bioengineers learn to encode in DNA can be grown whenever and wherever needed—essentially enabling the production of a wide range of products through biological processes across multiple sectors.

- The United States is still not executing well on strategies for emerging biotechnology and has relied too heavily on private-sector investment to support foundational work needed to scale and sustain progress.

- Biotechnology is one of the most important areas of technological competition between the United States and China, and China is now leveraging two decades of strategic investment to secure global leadership. Absent swift and ambitious actions, the United States risks biotechnological surprise and a loss of biotechnology sovereignty.

Cryptography and Computer Security

The word *cryptography* originates from Greek words that mean "secret writing." In ancient times, cryptography involved the use of ciphers and secret codes. Today, it relies on sophisticated mathematical models to protect data from being altered or accessed inappropriately. Cryptography is often invisible, but it is essential for most internet activities, such as messaging, e-commerce, and banking. In recent years, a type of cryptographic technology called blockchain—which records transactions in distributed ledgers in the computing cloud that cannot be altered retroactively without being detected—has been used for a variety of applications. These include time stamping and ensuring the provenance of information, identity management, supply chain management, and cryptocurrencies.

KEY CHAPTER TAKEAWAYS

- Cryptography is essential for protecting information, but alone it cannot secure cyberspace against all threats; it must operate in concert with the broader field of computer security.

- Cryptography is the enabling technology of blockchain, which is the enabling technology of cryptocurrencies.

- Rather than pursue a central bank digital currency, the United States has adopted a policy preference for privately issued digital assets, promoting stablecoins and cryptocurrencies as vehicles for financial innovation and resilience.

Energy Technologies

Energy is a vital strategic resource for nations that typically involves generation, transmission, and storage. Success in managing energy issues will depend on tackling the "energy trilemma," which is the task of balancing affordability and reliability with reduced greenhouse gas emissions. Energy mix and innovation are key to efforts addressing all three aspects of the trilemma. An important policy issue is achieving greater national consensus about energy goals to enable strategic and effective research and development (R&D) programs and funding.

KEY CHAPTER TAKEAWAYS

- Although many clean energy technologies are now available and increasingly affordable, scaling them up and building the infrastructure for them will take decades due to infrastructure inertia, stakeholder complexity, and the "energy trilemma," which balances reliability, affordability, and cleanliness.

- The US has shifted from climate urgency to energy dominance, redirecting support from renewables and electric vehicles to fission, coal, and natural gas. Globally, similar trends prevail as nations record peak fossil fuel use and scale back renewable investments, prioritizing energy security over decarbonization.

- Energy innovation is fragmented, diverse, and geopolitically strategic, with progress in technologies like fission, geothermal, fusion, and batteries reshaping the energy frontier. To compete with China, US technology leadership depends on sustained R&D funding, robust supply chains, and strategic industrial policies.

Materials Science

Materials science studies the structure and properties of materials—from those visible to the naked eye to microscopic features—and how they can be engineered to change performance. Contributions to the field have led to better semiconductors, "smart bandages" with integrated sensors and simulators to accelerate healing, more easily recyclable plastics, and more energy-efficient solar cells. Materials science has also been key to the development of additive manufacturing, often known as 3-D printing.

KEY CHAPTER TAKEAWAYS

- Materials science is a foundational technology that underlies advances in many other fields, including robotics, space, energy, and synthetic biology.

- The field will exploit artificial intelligence as another promising tool to predict new materials with new properties and to identify novel uses for known materials.

- Future progress in materials science requires new funding mechanisms and access to additional computational power to more effectively transition from innovation to implementation.

Neuroscience

Neuroscience is the study of the human brain and the nervous system—its structure, function, healthy and diseased states, and life cycle from embryonic development to degeneration in later years. The brain is perhaps the least understood and yet most important organ in the human body. Three major research subfields of neuroscience are neuroengineering (e.g., brain–machine interfaces), neurohealth (e.g., brain degeneration and aging), and neurodiscovery (e.g., the science of addiction).

KEY CHAPTER TAKEAWAYS

- Advances in human genetics and experimental neuroscience, along with computing and neuroscience theory, have led to some progress in several areas, including understanding and treating addiction and neurodegenerative diseases, and designing brain–machine interfaces for restoring vision.

- American leadership is essential for establishing and upholding global norms about ethics and human subjects research in neuroscience, but this leadership is slipping with decreased strategic planning and increased foreign investments in the field.

- Popular interest in neuroscience vastly exceeds the current scientific understanding of the brain, giving rise to overhyped claims in the public domain that revolutionary advances are just around the corner.

Quantum Technologies

Quantum technologies exploit the unusual principles of quantum mechanics, such as superposition and entanglement, to create new capabilities in computing, communication, and sensing. Quantum computers are moving toward solving problems that classical systems cannot, with applications in cryptography, materials science, and chemistry. Quantum networking may enable secure communications and scalable computing, while quantum sensors are already advancing navigation, medicine, and environmental monitoring. Though quantum technology (especially computing) is still relatively early in its development, global investment is accelerating, making sustained research and careful policymaking essential to balance innovation, security, and competition.

KEY CHAPTER TAKEAWAYS

- Quantum computing is advancing rapidly, making clear progress toward solving practical problems such as breaking existing public-key encryption algorithms, enabling new materials design, and supporting applications in chemistry. More speculative uses include machine learning, weather modeling, and financial portfolio optimization.

- Quantum networking and sensing are emerging as powerful technologies—networking may be critical for scaling computers to utility levels, while sensors are already transforming fields such as medical imaging and gravitational detection.

- Government-funded basic research in academic labs remains the foundation for breakthroughs, and sustained investment is essential to maintain leadership as companies push applications toward real-world utility.

Robotics

Robotics is an integrative field that draws on advances in multiple technologies rather than a single discipline. The question "What is a robot?" is harder to answer than it appears. At a minimum, the emerging consensus among researchers is that a robot is a physical entity that has ways of sensing itself and the world around it and can create physical effects on that world. Robots are already used across a range of sectors in a variety of ways—including assembly-line manufacturing, space exploration, autonomous vehicles, tele-operated surgery, military reconnaissance, and disaster assistance.

KEY CHAPTER TAKEAWAYS

- Artificial intelligence holds significant potential to advance complex robotic systems, but the speed of future advances will depend on the availability of high-quality training data and the systematic integration of data-rich foundation models, simulated interactions between robots and their environment, and understanding of the real physical world.

- Humanoid robots show promise for specialized industrial and healthcare roles, although widespread adoption of them faces challenges linked to their cost, technical complexity, energy efficiency, safety, and training data quality.

- Advances in autonomous, low-cost, and communication-resilient robotic systems are transforming important aspects of modern warfare.

Semiconductors

Semiconductors, or chips, are crucial and ubiquitous components used in everything from refrigerators and toys to smartphones, cars, computers, and fighter jets. Chip production involves two distinct steps: (1) design, which requires talented engineers to design complex integrated circuits involving millions of components, and (2) fabrication, which is the task of manufacturing chips in large, specially designed factories called "fabs." Because fabs involve highly specialized equipment and facilities, they can cost billions of dollars. US companies still play a leading role in semiconductor design, but capacity for semiconductor manufacturing in America has plummeted, leaving the country heavily dependent on foreign chips, most notably from Taiwan. The Creating Helpful Incentives to Produce Semiconductors (CHIPS) and Science Act of 2022 was intended to help the US semiconductor industry regain a foothold in fabrication, but progress will take years, if not decades.

KEY CHAPTER TAKEAWAYS

- The growing demand for artificial intelligence (AI) and machine learning is driving innovations in chip fabrication, along with advances in memory technologies and high-bandwidth interconnects such as photonic links, all of which are essential for enhancing computational power, managing energy efficiency, and meeting the increasing data needs of modern applications.

- Semiconductor manufacturing is the most precise manufacturing process that exists. It is used to advance work in energy and biotechnology in addition to information technology and AI.

- Strategic technology containment efforts directed against China help constrain Chinese capabilities in the short term. However, they are likely to drive China into a technology posture that is considerably more decoupled from the West and hence less vulnerable to Western pressure in the future.

Space

Space technologies include any technology developed to conduct or support activities approximately sixty miles or more beyond Earth's atmosphere. A single space mission is a system of systems—including everything from the spacecraft itself to propulsion, data storage and processing, electrical power generation and distribution, thermal control to ensure that components are within their operational and survival limits, and ground stations. While in the past, space was the exclusive province of government spy satellites and discovery missions, the number and capabilities of commercial satellites have increased dramatically in recent years. There were roughly one thousand total active satellites in orbit in 2014; today there are around eleven thousand—a figure that will likely rise to several tens of thousands in the next decade.

KEY CHAPTER TAKEAWAYS

- A burgeoning "NewSpace" economy driven by private innovation and investment is transforming space launch, in-space logistics, communications, and key space actors in a domain that until now has been dominated by superpower governments.

- Space is a finite planetary resource. Because of dramatic increases in satellites, debris, and geopolitical space competition, new technologies and new international policy frameworks will be needed to manage the traffic of vehicles, prevent international conflict in space, and ensure responsible stewardship of this global commons.

- The Trump administration has shifted priorities heavily toward human exploration of the Moon and Mars. This is at the expense of robotic exploration, space science, and aeronautics missions, leading to significant planned budget and personnel cuts to NASA. This trend may risk the long-term superiority of the United States in the global race for talent and technology.

Important Crosscutting Themes

Chapter 11 discusses fifteen themes that cut across the technological areas. We split these themes into four categories.

- **Governance and Geopolitics of Emerging Technology** examines how governments and political systems shape global technological progress.
  - Innovation that emerges too fast threatens the legitimate interests of those who might

be negatively affected, while innovation that moves too slowly increases the likelihood that a nation will lose first-mover advantages.

- National monopolies on technology are increasingly difficult to maintain. Even innovations that are solely American born (an increasingly rare occurrence) are unlikely to remain in the exclusive control of American actors for long periods.
- The US government is no longer the primary driver of technological innovation or funder of research and development (R&D).
- While democracies provide greater freedom for scientific exploration, authoritarian regimes can direct sustained funding and focus on technologies they believe are most important.

⟜ **Innovation Pathways and Patterns of Progress** explores the diverse ways in which technological progress unfolds.

- Technological progress is often unpredictable and nonlinear, with periods of slow development interrupted by sudden breakthroughs. While some fields, like semiconductors, have shown steady improvement, most technologies advance through cycles of experimentation, feedback, and convergence of multiple innovations.
- Nonscientific factors, such as engineering feasibility, economic viability, manufacturing challenges, and societal acceptance, influence the adoption of technology based on scientific advances.
- Hype can distort perceptions, leading to inflated expectations that outpace practical utility and distortions in resource allocation.
- Frontier bias causes overemphasis on new technologies and sometimes results in overlooking impactful uses of established ones.
- The synergies between different technologies are large and growing, which makes understanding the interactions between different fields all the more important.

⟜ **Human Capital and Knowledge Ecosystems** highlights the critical roles of people, universities, and funding structures in driving and sustaining innovation.

- Human capital is the foundation of scientific and technological progress. Sustained investment in it is the single most critical factor in ensuring long-term national competitiveness and scientific advancement.
- Universities are central to both high-risk research and science, technology, engineering, and mathematics (STEM) education. Yet federal R&D funding as a share of GDP has declined, and policy ambiguities hinder international collaboration.
- The "valley of death" between research feasibility and commercial viability remains a major barrier to advancing innovations to market. New funding models are needed to bridge this gap and sustain America's technological leadership.

⟜ **Infrastructure for Innovation** encompasses vital systems and structures that support innovation on a large scale.

- Standards enable interoperability, lower costs, and support global trade but can also stifle innovation and be manipulated for market control or geopolitical advantage.
- Manufacturing is vital for economic resilience and security, especially amid global supply chain disruptions and strategic competition with China and other nations. Technological advances like robotics and artificial intelligence are reshaping production, while

policies such as the CHIPS and Science Act of 2022 aim to boost domestic capacity.

- Cybersecurity protects data, systems, and intellectual property from threats, ensuring research integrity and confidentiality. However, maintaining robust security can conflict with the open culture of research environments.

Finally, each of the ten technology fields covered in this report bears on five policy areas that are of interest to policymakers: economic growth, national security, environmental and energy sustainability, health and medicine, and civil society. Chapter 12 identifies applications and consequences of each field as they apply to these policy areas.

This publication reflects updates through December 2025

32 31 30 29 28 27 26 7 6 5 4 3 2 1

Designer: Howie Severson
Typesetter: Maureen Forys

Image credits: Linda A. Cicero/Stanford News and iStock.com/PTC-KICKCAT92 (cover); iStock.com/mofuku (p. 22); iStock.com/wacomka (p. 38); iStock.com/FeelPic (p. 56); iStock.com/JONGHO SHIN (p. 70); iStock.com/Chartchai San-saneeyashewin (p. 88); iStock.com/ArtemisDiana (p. 102); iStock.com/PhonlamaiPhoto (p. 116); iStock.com/imaginima (p. 142); iStock.com/Floriana (p. 156); iStock.com/dima_zel (p. 170); Tim Griffith (p. 225)