

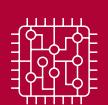
STANFORD UNIVERSITY

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



FOREWORD

This edition of the Stanford *Emerging Technology Review* (SETR) coincides with the 250th anniversary of America's Declaration of Independence. As we look toward the future, the past reminds us that history takes surprising turns and that human agency can be powerful. In 1776, few could have dreamed that a ragtag band of colonists in a backwater far from Europe would defeat a great power, replace a king with an extraordinary experiment in democracy, and ultimately become the technological envy of the world. What looked impossible two and a half centuries ago seems inevitable now. Bold ideas and determined action made all the difference.

Today, we face a hinge of history moment where technological discoveries are supercharging both possibility and risk at dizzying speed. This emerging world is hard to understand and even harder to anticipate. But this much seems clear: The choices made today, in everywhere from labs to legislatures, are likely to have consequences for generations. Artificial intelligence (AI) is poised to transform scientific discovery, the future of work, the future of war, and more. And AI is not alone. From nanomaterials that are fifty thousand times smaller than the width of a human hair to commercial satellites and other private-sector technologies deployed in outer space, breakthroughs are reshaping markets, societies, and geopolitics. This is a convergence moment: Never have so many technologies changed so much so fast.

In this era, US technology policy is no longer the unique province of government that it used to be. Federal and state officials are struggling to keep up with technological advances and their implications. At the same time, inventors and investors are struggling to reconcile commercial opportunities and national interests in a world where technology, economics, and geopolitics have become inseparable.

Now more than ever, understanding the landscape of discovery and how to harness technology to forge a better future requires working across sectors, fields, and generations. Engineers and executives need to better understand the policy world to anticipate how their decisions could generate geopolitical advantages and vulnerabilities, and how they can seize opportunities while mitigating risks to the nation. Government leaders need to better understand the academic and business worlds so that well-intended policies don't end up exacerbating societal harms or dampening America's innovation leadership and the geopolitical advantages that come with it. And both government and industry need to better understand the foundational role that America's research universities play in the ecosystem that has made the United States the world's innovation leader since 1945—and how that model is now weakening at home while China is racing to copy it.

The Stanford Emerging Technology Review (SETR) initiative is the first-ever collaboration between Stanford University's School of Engineering, the Hoover Institution, and Stanford's Institute for Human-Centered Artificial Intelligence. We launched this effort with an ambitious goal: transforming technology education for decision makers in both the public and private sectors so that the United States can seize opportunities, mitigate risks, and ensure the American innovation ecosystem continues to thrive.

This is our third annual report surveying the state of ten key emerging technologies and their implications. It harnesses the expertise of leading faculty in science and engineering fields, economics, international relations, and history to identify key technological developments, assess potential implications, and highlight what policymakers should know.

This report is our flagship product, but it is just one element of our continuous technology education campaign for policymakers that now involves more than one hundred Stanford scholars across forty departments and research institutes. In the past year, SETR experts have briefed senior leaders in the private sector and across the US government—in Congress, the White House, the Department of Commerce, the Department of Defense, and the intelligence community. We have organized and participated in dozens of Stanford programs, including multiday congressional staff boot camps in AI, biotechnology, and emerging technologies more broadly; roundtables for CEOs, national media, state and local leaders, and officials from European partners and allies; and workshops convening leaders across sectors to develop new insights that advance space policy, America's biotechnology strategy, defense innovation, and economic statecraft.

Our efforts are guided by three observations:

1. America's global innovation leadership matters.

American innovation leadership is not just important for the nation's economy and security. It is the linchpin for maintaining a dynamic global technology innovation ecosystem and securing its benefits for the United States and the world.

Put simply, it matters whether the global innovation ecosystem is led by democracies or autocracies. Democratic countries promote freedom and thrive in it, while authoritarian countries do not. Freedom, in turn, is the fertile soil of innovation, and it takes many forms: the freedom to criticize a government; to admit failure in a research program as a step toward future progress; to share findings openly

with others; to collaborate across geographical and technical borders with reciprocal access to talent, knowledge, and resources; and to work without fear of repression, persecution, or political reprisal.

But the United States cannot succeed alone. Robust international collaboration, especially with allies and partners, is essential for bringing together the best minds to tackle the world's toughest challenges, accelerating technological breakthroughs, and advancing American values, not just our interests.

China's rise poses many challenges, and we must not be naive about the Chinese Communist Party's espionage activities and intellectual property theft from American companies and universities or its spread of repressive surveillance technologies around the world. But it is also worth remembering that international scientific collaboration has long been pivotal to fostering global peace, progress, and prosperity, even in times of intense geopolitical competition. During the Cold War, American and Soviet nuclear scientists and policymakers worked together to reduce the risk of accidental nuclear war through arms control agreements and safety measures—at the same time as their nuclear weapons were targeting each other's cities. Similarly, scientific cooperation with China is essential today for reducing shared risks posed by new technologies, from AI-enabled nuclear command and control disasters to conflict in outer space that could bring devastating unintended or unexpected consequences for commercial activities and civilian life.

2. Academia's role in American innovation is essential—and at risk.

America's thriving innovation ecosystem has rested on three pillars: the government, the private sector, and

the academy. Success has required robust research and development (R&D) in all three. But they are not the same. Evidence suggests that universities' role as the engine of innovation is increasingly at risk, and there is no plan B.

Universities, along with US national laboratories, are the only institutions that conduct research on the frontiers of knowledge without regard for potential profit or foreseeable commercial application. This kind of research is called basic or fundamental research. It takes years, sometimes decades, to bear fruit. And it often fails, because fundamental research is in the business of asking big, hard questions to which nobody knows the answers. But without this kind of research over long periods of time, future commercial innovations would not be possible. Fundamental research investigates questions like, "What are the principles of quantum physics?" and "How does the human immune system work?" Commercial research then builds on openly published academic work to develop quantum computing start-ups whose work could help identify new materials or develop medicines that save millions of lives.

Much of our daily life depends on breakthroughs that would never exist without years of federal investment in fundamental research inside universities. The internet, radar, magnetic resonance imaging (MRI) machines, and the Global Positioning System (GPS) for navigation are just a few examples. Today's AI revolution began fifty years ago with university research into neural networks.

Everyone uses Google, but few people know that Google emerged from a National Science Foundation grant to Stanford professors who were

conducting fundamental research on digital libraries back in 1993—when there were one hundred total websites on Earth.¹

However, there are signs that the engine of innovation in US research universities is not running as well as it could, posing long-term risks to the nation and our technological leadership. In 2024, for the first time, the number of Chinese contributions surpassed ones from the United States in the closely watched *Nature Index*, which tracks eighty-two of the world's premier science journals.² Increasingly, the world's best and brightest are not automatically coming to the United States to be educated and possibly stay; global talent has far more educational and training options now than it did ten or twenty years ago. For example, a 2025 Hoover Institution study found that more than half of China's leading AI researchers behind DeepSeek's breakthrough large language model (LLM) were educated and trained entirely in China.³ In today's technological era, knowledge really is power, and it starts with talent.⁴ Reversing the downward slide of American K-12 education at home and recruiting and retaining the brightest minds from abroad have never been more important for American technological competitiveness and national security.

Universities have work to do to fulfill our mission of promoting serious and searching inquiry, restore civic discourse, and regain the trust of the American people. Making cosmetic changes and hoping to return to the way things were will not be enough; this is a moment to reimagine and reinvigorate higher education in service of discovery and the nation. At the same time, the current challenges across US campuses should not distract from the urgent need

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to ensure American research universities have what it takes to make the breakthrough discoveries of tomorrow. We are harvesting today the research seeds planted decades ago. But we are not planting for the future like we once did.

The US government is the only funder capable of making large and risky investments in the basic science conducted at universities (as well as national laboratories) that is essential for future applications. Yet federal R&D funding has plummeted in percentage terms since the 1960s, from 1.86 percent of GDP in 1964 to just 0.66 percent of GDP in 2016.⁵ The United States used to spend more of its GDP on science and research than any nation in the world; today the US ranks eighth.⁶

The Creating Helpful Incentives to Produce Semiconductors (CHIPS) and Science Act of 2022 was supposed to begin reversing this yearslong decline by dramatically increasing federal funding for basic research. But those increases were subsequently scrapped. Current budget proposals call for further reductions in the National Science Foundation budget (which funds all fields of fundamental science and engineering outside of medicine) and the National Institutes of Health budget (which funds medical research).

The United States still funds more basic research than China does, but China is copying the US innovation playbook by investing more and more in basic research and concentrating talent in research universities. In fact, China's basic research investment is rising six times faster than that of the United States. As figure F.1 illustrates, China is poised to overtake the US by the end of the decade if current trends continue.

Private-sector investment in technology companies and associated university research has increased substantially over time, and it may seem like an attractive substitute. But it is not the same. Private investors (rightly) expect returns on their investment, which naturally leads them to fund research avenues with a

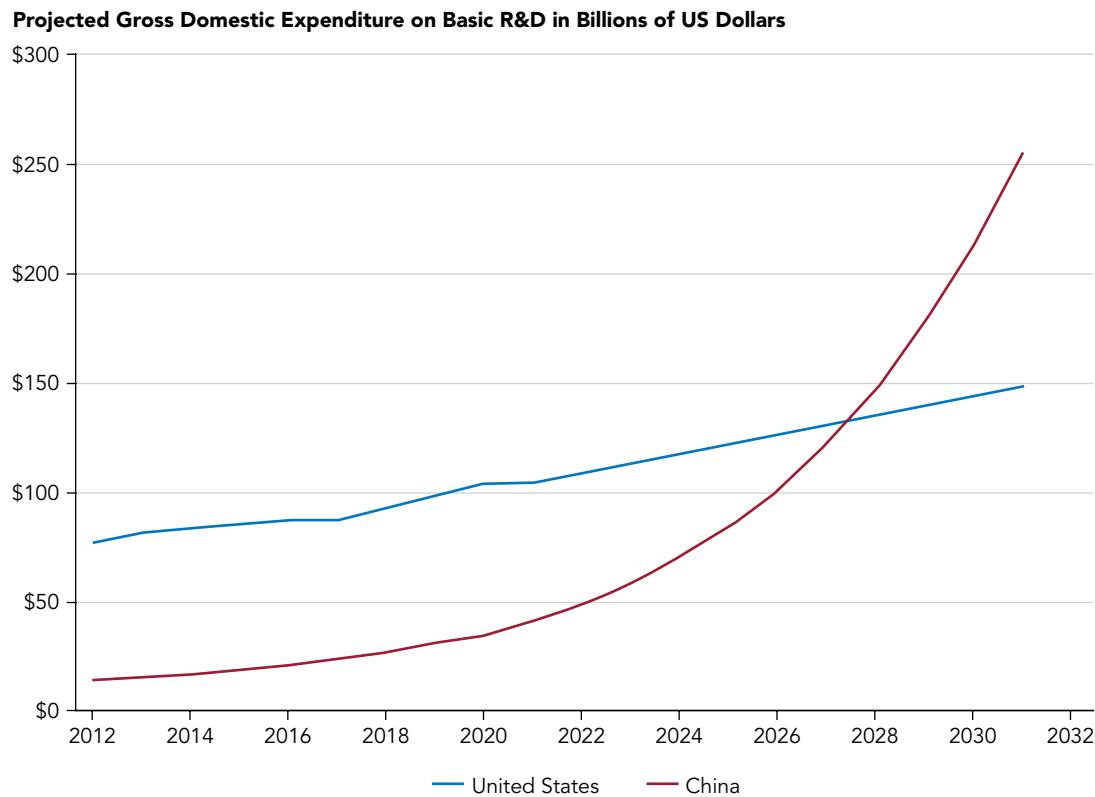
shorter-term focus and commercial viability. Federal funding for basic research, by contrast, is directed at research that has no foreseeable profit but addresses national issues for the public benefit, seeks to advance basic understanding, and can take a longer-term view to pursue moonshot ideas.⁷

To be sure, the rising dominance of private industry in innovation brings significant benefits. But it is also generating serious and more hidden risks to the health of the entire American innovation ecosystem. In some areas, technology and talent are migrating from academia to the private sector, accelerating the development of commercial products while eroding the foundation for the future. We are already reaching a tipping point in AI. In 2022, more than 70 percent of students who received PhDs in artificial intelligence at US universities took industry jobs, leaving fewer faculty to teach the next generation.⁸ As the bipartisan National Security Commission on Artificial Intelligence put it, "Talent follows talent."⁹

Today, only a handful of the world's largest companies have both the talent and the enormous compute power necessary for developing sophisticated LLMs like ChatGPT. No university comes close. In 2024, for example, Princeton University announced that it would tap endowment funds to purchase 300 advanced NVIDIA chips to use for research, costing about \$9 million, while Meta announced plans to purchase 350,000 of the same chips by year's end at an estimated cost of \$10 billion.¹⁰

These trends raise several concerning implications.¹¹ A very significant one is that research in the field is likely to be skewed to applications driven by commercial rather than public interests. The ability for universities—or anyone outside of the leading AI companies—to conduct independent analysis of the weaknesses, risks, and vulnerabilities of AI (especially LLMs recently in the news) will become more important and simultaneously more difficult. Further, the more that industry offers unparalleled talent concentrations, computing power, training data, and the most sophisticated models, the more likely it is that

FIGURE F.1 China is projected to overtake the United States in basic research and development spending



Note: The projection assumes the rate of change between 2012 and 2024 continues forward; it does not include the Trump administration's proposed FY 2026 budget reductions to federally funded research.

Source: OECD Main Science and Technology Indicators Dataset, <https://www.oecd.org/en/data/indicators/gross-domestic-spending-on-r-d.html>

future generations of the best AI minds will continue to flock there, potentially eroding the nation's ability to conduct broad-ranging foundational research in the field.

3. The view from Stanford is unique, important—and needed now more than ever.

Stanford University has a unique vantage point when it comes to technological innovation. It is not an accident that Silicon Valley surrounds Stanford; technology developed at Stanford in the 1930s served as the foundation for the pioneering companies

like Varian Associates and Hewlett-Packard that first shaped industry in the Valley. Since then, the university has continued to fuel that innovation ecosystem. Stanford faculty, researchers, and former students have founded Alphabet, Cisco Systems, Instagram, LinkedIn, NVIDIA, Sun Microsystems, Yahoo!, and many other companies, together generating more annual revenues than most of the world's economies. Start-ups take flight in our dorm rooms, classrooms, kitchens, and laboratories. Technological innovation is lived every day and up close on our campus—with all its benefits and downsides. This ecosystem and its culture, ideas, and perspectives often seem a world apart from the needs and norms

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of Washington, DC. Bridging the divide between the locus of American policy and the heart of American technological innovation has never been more important.

Stanford has a rich history of policy engagement, with scholars and alumni who serve at the highest levels of government as well as institutional initiatives that bring together policymakers and researchers to tackle the world's toughest policy problems. And generations of Stanford engineering faculty, students, and staff have had profound impact through their discoveries—from the klystron, a microwave amplifier developed in the 1930s that enabled radar and early satellite communications; to the algorithms driving Google; to optogenetics, a technique pioneered in 2005 that uses light to control neurons, enabling precise studies of brain function. In this moment of technological change, we must do even more to connect emerging technologies with policy. We are proud and excited to continue this unprecedented collaboration to bring policy analysis, social science, science, medicine, and engineering together in new ways.

Today, technology policy and education efforts are often led by policy experts with limited technological expertise. The *Stanford Emerging Technology Review* flips the script, enlisting many of the brightest scientific and engineering minds at the university to share their knowledge of their respective fields by working alongside social scientists to translate their work to nonexpert audiences. We start with science and technology, not policy. And we go from there to emphasize the important interaction between science and all aspects of policy.

How to Use This Report: One Primer, Ten Major Technology Areas

This report is intended to be a one-stop shopping primer that covers developments and implications in ten major emerging technology areas: artificial intelligence; biotechnology and synthetic biology; cryptography and computer security; energy technologies; materials science; neuroscience; quantum technologies; robotics; semiconductors; and space. The list is broad by design, and it includes fields that are widely regarded as pivotal to shaping society, economics, and geopolitics today and into the future.

That said, the ten major technology areas covered in this report are nowhere near an exhaustive catalog of technology research areas at Stanford. And the list may change year to year—not because a particular technology sputtered or we got it wrong, but because categorizing technologies is inherently dynamic; because limiting this report to ten areas imposes discipline on what we cover and how deeply we go; and because we seek to highlight relationships among technologies in ways that may not be obvious. Quantum computing, for example, used to be covered in our chapter on semiconductors, but it is included in a new chapter on quantum technologies this year because of so much current interest in and concern about quantum computing, sensing, and communications. We had a separate chapter on

lasers last year, but this year's report folds lasers into our crosscutting themes analysis because the field is more of an enabling technology. Of note, nine of the ten technology chapters appearing in this edition are the same from 2025, and eight of the ten are the same in all three editions of the report.

We have expanded our treatment of issues that cut across technological fields because these are both important and often overlooked. Themes include nonobvious insights that are important for decision makers to remember—like “frontier bias,” which is the natural but mistaken assumption that transformational technologies sit on only the frontiers of a field. Indeed, DeepSeek AI’s LLM release last year is a cautionary tale that should remind us there are many pathways to success and that not all of them require the most advanced computational resources that American technology firms currently have.

For each of the ten technology chapters, reviews of the field were led by world-renowned, tenured Stanford faculty members who also delivered seminars to faculty contributors, discussants, and SETR advisory board members within and outside their areas of expertise (bios of SETR faculty and contributors can be found at the end of this report). The SETR team also involved more than a dozen post-doctoral scholars and undergraduate research assistants who interviewed faculty across Stanford and drafted background materials.

Each technology chapter begins with an overview of the basics—the major technical subfields, concepts, and terms needed to understand how a technology works and could affect society. Next, we outline important developments and advances in the field. Then we provide an over-the-horizon view of the technology and its future development. Each chapter concludes with a policy section that covers the most crucial considerations for policymakers over the next few years. The report ends with a chapter that looks across the ten technologies, offering analysis of implications for economic growth, national

security, environmental and energy sustainability, health and medicine, and civil society.

Three points bear highlighting. First, **we offer no specific policy recommendations in this report.** That is by design. Washington is littered with reports offering policy recommendations that were long forgotten, overtaken by events, or both. Opinions are plentiful. Expert insights based on leading research are not.

We aim to provide a reference resource that is both timeless and timely, an annual state-of-the-art guide that can inform successive generations of policymakers about how to think about evolving technological fields and their implications. Individual SETR faculty may well have views about what should be done. Some of us engage in policy writing and advising. But the mission of this collective report is informing, not advocating. We encourage readers interested in learning more about specific fields and policy ideas to contact our team at SETReview2026@stanford.edu.

Second, **SETR offers a view from Stanford, not the view from Stanford.** There is no single view of anything in a university. Faculty involved in this report may not agree with everything in it. Their colleagues would probably offer a different lay of the technology landscape with varying assessments about important developments and over-the-horizon issues. This report is intended to reflect an informed judgment about the state of these ten fields—guided by SETR’s faculty.

Third, **this report is intended to be the introductory product that translates a broad swath of technological research for nontechnical readers.** Other SETR offerings provide deeper dives into specific technological areas that should be of interest for subject-matter experts.

Ensuring continued American leadership in science and technology is essential, and it’s a team effort. We hope this third edition of the *Stanford Emerging Technology Review* continues to spark meaningful

dialogue, better policy, and lasting impact. The promise of emerging technology is boundless if, like our founding fathers, we are willing to pursue bold ideas and take determined action.

Condoleezza Rice

Jennifer Widom

Amy Zegart

Co-chairs, Stanford Emerging Technology Review

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