Taking the Helm

A National Technology Strategy to Meet the China Challenge

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About the Report

This report is produced as part of the U.S. National Technology Strategy project at CNAS. The project is developing the intellectual framework for a national technology strategy for the United States that can serve as a road map for successful long-term American innovation and technological leadership. The project focuses on how the government should establish technology policy on key issues such as accelerating American innovation, mitigating risk to U.S. advantages, and contending with the technology strategies of competitors. This report was made possible because of a grant from the U.S. Air Force Office of Commercial and Economic Analysis (OCEA).

This report draws on analysis and insights from forthcoming and prior CNAS reports, including:

"Networked: Techno-Democratic Statecraft for Australia and the Quad," by Martijn Rasser (Early 2021)

"Democracy by Design: An Affirmative Response to the Illiberal Use of Technology for 2021," by Kara Frederick (December 2020)

"Rethinking Export Controls: Unintended Consequences and the New Technological Landscape," by Martijn Rasser (December 2020)

"Defense Technology Strategy," by Paul Scharre and Ainikki Riikonen (November 2020)

"Common Code: An Alliance Framework for Democratic Technology Policy," by Martijn Rasser, Rebecca Arcesati, Shin Oya, Ainikki Riikonen, and Monika Bochert (October 2020)

"Rising to the China Challenge: Renewing American Competitiveness in the Indo-Pacific," by Ely Ratner et al. (January 2020)

"The American AI Century: A Blueprint for Action," by Martijn Rasser, Megan Lamberth, Ainikki Riikonen, Chelsea Guo, Michael Horowitz, and Paul Scharre (December 2019)

Table of Contents

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Executive Summary

The United States faces a challenge like no other in its history: a strategic competition with a highly capable and increasingly resourceful opponent whose worldview and economic and political models are at odds with the interests and values of the world's democratic states. A rising China poses a fundamental challenge to the economic vitality and national security of the United States and its allies and the currency of liberal democratic values around the world. Technology—a key enabler for economic, political, and military power—is front and center in this competition.

Technological leadership—how a country invents, innovates, and deploys technologies to compete economically and to secure its interests—will shape the coming years to a remarkable degree. The United States has maintained such leadership for decades. Today, that leadership is at risk. The United States is failing to rise to the occasion—its policies inadequate and disconnected and its response reactive and disjointed. The country needs a new approach to regain the initiative. The stakes are high and the window for action is closing.

The U.S. government must craft a national technology strategy for an era of sustained competition with a highly capable contender: a comprehensive framework to plan, execute, and update its technology policies. The strategy is a whole-of-nation approach—including human capital, infrastructure, investments, tax and regulatory policies, and institutional and bureaucratic processes—to preserve its current advantages and to create new ones. To be effective, creating and executing the strategy must involve stakeholders from federal and state governments, private industry, academia, and civil society. The overarching goal is to maintain the United States' standing as the world's premier technology power so that it can empower its citizens, compete economically, and secure its national interests without having to compromise its values or sovereignty.

The purpose of this report is to provide the intellectual framing for what a national technology strategy is and why the United States needs one. It does not offer a list of prioritized technology areas. Rather, it provides guidelines for how to think about such prioritization and what qualities should inform the resulting policy decisions.

A successful U.S. national technology strategy will require a recalibration of government involvement in the country's science and technology (S&T) base. The report addresses why the United States should revisit key lessons of successful technology policies during World War II and throughout the Cold War and apply them in the current context. This does not mean heavy-handed interventions of "picking winners and losers" and other unnecessary and damaging market distortions. We recommend a technology policy that focuses on actions to promote American competitiveness, protect American technological advantages, partner with like-minded countries to maximize success, and plan for effective strategy updates.

The specific recommendations offered form the foundation for this national technology strategy. They are the bedrock for long-term American competitiveness.

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SUMMARY OF RECOMMENDATIONS

"Vision without action is a daydream. Action without vision is a nightmare."
-Japanese proverb

Strategy without execution is meaningless. This report offers an initial framework for action to achieve the vision and goals of a new American national technology strategy. It comprises four pillars. They are to *promote* America's ability to compete; *protect* key U.S. technological advantages; *partner* with allies to maximize success; and *plan* to reevaluate and adjust the strategy as needed. Together they provide the foundation for long-term American economic strength and improved U.S. national security.

Promote America's Capacity to Compete

The United States must take swift and wide-ranging action to ensure the long-term competitiveness of its science and technology base.

- *Boost research and development (R&D) investments.* The U.S. share of global R&D spending and the R&D spending growth rate have declined precipitously since the 1970s. Congress should:
    - Raise federal spending on R&D to at least 2 percent of gross domestic product (GDP) by 2030.
    - Promote incentives to increase total (public and private) R&D investments to at least 4.5 percent of GDP by 2030.
- *Develop and execute a national human capital strategy.* The United States faces an acute talent and skills shortfall in the technology areas that will drive the future economy. The White House and Congress should:
    - Expand public- and private-sector science, technology, engineering, and math education and skills training to grow and sustain America's science and technology (S&T) workforce.
    - Address high-skilled talent retention challenges in academia by reversing the decline in federal grants to universities and colleges.
- *Attract and retain the world's best and brightest S&T talent.* The United States reaps untold benefits from having international talent work and live in this country. Congress should:
    - Raise the cap for H-1B visas and remove the cap for advanced-degree holders entirely.
    - Amend the Department of Labor Schedule A occupations list to include high-skilled technologists.
    - Create a new program that couples visa grants to 10-year open-market work commitments.[1]

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- *Expand access to S&T infrastructure and resources.* Researchers in the United States face uneven access to necessary digital infrastructure. Congress and the White House should work together to:
    - Establish a National Research Cloud, such as those proposed by the Stanford Institute for Human-Centered Artificial Intelligence and the National Security Commission on Artificial Intelligence.
    - Improve digital infrastructure, such as by encouraging rollouts of private 5G networks to provide broadband to rural areas.

Protect Critical U.S. Technological Advantages

The U.S. government needs to address complex and critical issues to preserve areas of technological advantage, an important driver for long-term American competitiveness.

- *Reframe the goal of export controls.* Export control policies should be focused on foreign tech indigenization efforts to regain their power as an effective instrument in foreign and national security policymaking. The U.S. government should:
    - Enact multilateral export controls on semiconductor manufacturing equipment to China in cooperation with key partners, rather than focusing on the chips themselves. The United States and its allies have no strategic interest in China gaining the ability to design and fabricate cutting-edge chipsets; selling chips to China, however, can be done without impairing U.S. national security.
- *Counter and mitigate unwanted tech transfers.* Technology theft costs the U.S. economy hundreds of billions of dollars each year.
    - Provide more cyberdefense support to small firms, which generally are more vulnerable to cyberattacks.
    - Authorize consular officials to act on risk indicators for espionage to screen out high-risk individuals before they arrive.[2] For example, the Trump administration took good action on this by denying visas to Chinese nationals with direct ties to universities affiliated with the People's Liberation Army.
    - Improve collaboration between U.S. counterintelligence experts and academic leaders, such as by reestablishing the National Security Higher Education Advisory Board that served as a forum for communication between universities and the national security community.
- *Restructure critical supply chains.* Many U.S. supply chains are dangerously brittle and present vulnerabilities that must be addressed.
    - Diversify and secure those supply chains where vulnerabilities pose an unacceptable risk to U.S. national security, economic security, and core necessities.[3]

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Partner with U.S. Allies to Maximize Success

The United States must revamp and expand collaborative technology policy efforts with allied and partner countries to effectively compete with China and address critical global challenges.

- *Enhance bilateral and multilateral research efforts.* Adequate R&D investment is critical to sustaining U.S. technological competitiveness.
    - Establish international R&D centers to spur multilateral collaboration on basic and applied research, allowing for cost sharing and increased interoperability across countries, as well as the alignment of complementary knowledge and experience.
- *Create a human capital network to foster multilateral collaboration.* A robust talent pipeline is fundamental for sustained U.S. technological competitiveness.
    - Create a network for multilateral collaboration where scientists, technologists, and engineers from allied and partner countries can travel, work, and live in participating countries.
- *Codify norms for technology use.* Technology-leading nations will have outsized influence in shaping the norms and principles for how technologies should and should not be used.
    - Lead like-minded countries on setting norms for the responsible use of technologies consistent with liberal democratic values. This should include foundational and emerging technologies and their broad application such as for AI, surveillance technology, and cyberspace.
- *Reclaim the integrity of international standard-setting.* China is pursuing a comprehensive strategy to have Chinese-origin technologies be the foundation for global technology platforms and reduce its dependence on foreign intellectual property (IP) and standards.
    - Preserve the integrity of global standard-setting by making resources available for companies to send full delegations and submit the broadest possible portfolio of technologies to standard-setting bodies for consideration, and to call for reforms of the bodies to prevent bloc-voting.
    - Take a more involved role in global standard-setting by building stronger ties with stakeholders in foreign governments and private industry, and taking leadership roles in setting standards such as by convening or administering consensus groups.[4]
- *Establish a network of like-minded countries to collaborate on technology policy.* Technology policy coordination among like-minded countries is often sporadic and disjointed.
    - Create a multilateral technology alliance with a core group of like-minded countries to collaborate on technology policy.[5] A formal grouping of allied countries could focus their efforts on collaborative research on next-generation technologies, securing and diversifying supply chains, protecting critical technologies, and cooperating on international standard-setting and norms creation.[6]

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Plan for Regular Strategy Updates

The rapid and unpredictable nature of technological change means that the national technology strategy will require frequent reassessment.

- *Review technology goals and their underpinning assumptions regularly.* Once-promising technologies may lose their luster, tactical objectives may change, competitors can achieve technology surprise, and unforeseen opportunities could present themselves.
    - Create a repeatable and transparent process to update technology priorities for the national technology strategy and specific strategies for foundational technology areas such as AI, quantum science, semiconductors, biotechnology, and wireless telecommunications.
- *Maintain multistakeholder input.* A national technology strategy is a whole-of-nation effort that requires buy-in and participation from all relevant segments of American society.
    - Commit to ongoing engagement between the public and private sectors and civil society.
- *Bolster U.S. government capabilities for assessing technology development and trends.* Minimizing the risk of technology surprise and anticipating change strengthens strategy.
    - Establish and expand permanent technology analysis capabilities, including horizon scanning, net assessments, and technology forecasting.

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Introduction

Advances in emerging technologies will transform the way economies operate, militaries fight wars, and societies and individuals interact. Future developments in key technology areas such as artificial intelligence (AI), quantum sciences, next-generation telecommunications, and biotechnology are likely to generate opportunities for greater economic prosperity, strengthened national security, and a more just and equitable society. Emerging technologies can be used to address pressing global issues, such as climate change, food insecurity, or global pandemics.

At the same time, technological change could result in widespread disruption to economies, labor markets, militaries, and societies. Increased automation in the workforce could lead to job loss and stagnated incomes. A rise in digital surveillance technologies, aided by an astronomical growth in data, could be used to repress the civil liberties of populations around the globe. Militaries in the heat of battle could feel pressure to deploy untested, potentially destabilizing technologies.

Technology-leading nations will have outsized influence over where the balance of these possible futures will lie and shape the arc of international peace and security. The stakes of the geostrategic competition are high.

Yet the United States faces this technology competition without a coherent national approach. U.S. technology policymaking has been reactive, ad hoc, lacking in a strategic approach, and occasionally counterproductive. The U.S. government must adopt a unified, long-term strategic framework to guide national technology policymaking in order to reap the benefits of advanced technology while limiting its harm. The federal government needs a national approach to accelerate American innovation, mitigate risk to U.S. advantages, and contend with the technology strategies of its competitors, particularly that of the Chinese Communist Party (CCP). In this era of U.S.-China geostrategic competition, the United States needs a national technology strategy that promotes economic prosperity, security, and democratic values and counters the CCP's technology-enabled authoritarianism and anti-competitive economic practices.

This report provides a road map for how the United States should compete. It proposes a framework for 1) how the United States should approach its technology policy priorities and 2) a schema to help guide the government's prioritization of key technologies. The report also examines certain cases throughout U.S. history where the federal government enacted successful technology strategies. Finally, the report offers a series of policy recommendations to help guide the U.S. government's formation and execution of a national technology strategy.

This report is the first in a series of papers on crafting the intellectual basis for a national approach to technology policy. This report is not all-encompassing. Subsequent papers will dive deeper into the concrete steps the U.S. government must take to develop and execute a national technology strategy, including the institutional and bureaucratic processes necessary to implement such a strategy.

Ultimately, this report aims to shake the U.S. government free of its complacency. The United States must tap into its remarkable innovation base—its economic resources, talent, and robust industry—to face this century's greatest threats and compete with a rising China.

The Case for a National Technology Strategy

America's science and technology (S&T) base—the people and the infrastructure and resources they use to create and innovate—has long been a source of military, economic, and diplomatic power. The government's current approach to technology policy—passive and piecemeal—is inadequate for tackling the geostrategic challenges ahead. For the United States to fully capitalize on its innovation base and maintain its competitiveness, it needs an overarching approach to guide its technology policy decisions. The case for why the United States needs a national technology strategy is twofold. First, the United States is engaged in a long-term, multifaceted geostrategic competition with China. This competition has technology at its core.[7] Second, the United States needs an enduring and affirmative framework to guide its technology policy—one that seeks to build and apply technologies that promote security and economic prosperity and seeks to ensure the betterment of society both in the United States and abroad. U.S. technological leadership is more important than ever, but America's position is at risk.[8]

COMPETING WITH CHINA

Key elements of U.S. technological competitiveness, particularly federal research and development (R&D) investments and human capital are strained. Federal government spending on R&D as a percentage of gross domestic product (GDP) is far lower than in decades past.[9] In 1960, the United States accounted for nearly 70 percent of global R&D funding.[10] By 2018, that percentage had fallen to 28 percent.[11] Meanwhile, China is investing heavily in R&D and is on track to surpass the United States in total national R&D spending by the mid-2020s.[12] The mix of U.S. R&D spending also shifted dramatically during this time period: while the private sector continues to increase its R&D expenditures, federal government spending has declined as a percentage of GDP from approximately 1.2 percent in 1976 to around 0.7 percent in 2018.[13] This is problematic for sustained technological competitiveness because the U.S. government is the largest funder of basic research, the activities where most breakthroughs happen.

The trend lines on matters of human capital are also worrisome. America's talent pipeline, the bedrock of U.S. technological leadership, is deteriorating from underinvestment in science, technology, engineering, and math (STEM) education and increasingly restrictive policies for high-skilled immigrants.[14] As it becomes harder for foreign talent to live and work in the United States, other countries are opening their doors.[15] Attracting and retaining talent is a true zero-sum element of the overall competition.

America's technology dominance is waning as a result. While China has developed and implemented long-term national strategies for technological competitiveness, the U.S. approach has been far more reactive and disjointed. The rivalry between the United States and China in 5G wireless is emblematic in many ways of the technology competition between the two countries. The Chinese government was preparing for 5G years before the United States, championing the Chinese firm Huawei, which clinched outsized global market share and threatened the integrity and independence of U.S. allies' 5G networks and associated critical infrastructure.[16]

While China's competitive edge in 5G was a wake-up call for U.S. policymakers, the scale of the challenge is much greater. U.S. technological leadership is at a critical juncture. China represents a dynamic and fast-growing challenge to American global technological leadership. China is no longer a nation of copying but is engaging in true innovation and is a serious technological competitor. In a number of critical technology areas—AI, quantum sciences, biotechnology—China is at a position of rough parity or has surpassed the United States.[17] China's desire to be a "science and technology superpower" is driven by a number of national strategies—Made in China 2025, Belt and Road Initiative, China

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Standards 2035, strategy on military-civil fusion, among others.[18] Under these umbrella strategies, China has implemented sector-specific approaches, such as the New Generation Artificial Intelligence Development Plan or the country's National Laboratory for Quantum Information Science.[19]

China is an increasingly capable technology power with ambitious goals to be the global leader in technological innovation. Here, an unmanned aerial vehicle is showcased in a 2019 military parade commemorating the 70th anniversary of the establishment of the People's Republic of China. (Andrea Verdelli/Getty Images)

The United States has no equivalent to China's national approach.[20] The Trump administration's National Strategy for Critical and Emerging Technologies (October 2020) attempts to fill this void; however, it lacks implementation guidance and enforcement mechanisms.[21] The United States also has a number of technology-specific strategies, such as Maintaining American Leadership in Artificial Intelligence (February 2019), the National Quantum Initiative Act (December 2018), and the National Strategy to Secure 5G (March 2020), but these disparate strategies lack an overarching approach to tie them together.[22] Congress, meanwhile, is debating a range of ambitious legislative proposals that would offer tens of billions in funding for a range of foundational and emerging technologies.[23] While well-intended, there is no coherent strategic framework to tie these assorted efforts together.

The U.S. government's response to China's digital authoritarianism and illicit economic practices has similarly been disjointed. The U.S. government has countered China's actions—intellectual property (IP) theft, forced technology transfer, and commercial and academic espionage—through existing tools of economic statecraft. The use of these powerful and effective tools—export controls, enhanced investment screening, and targeted sanctions—must be guided by a consistent, repeatable approach.

The United States cannot apply a one-size-fits-all solution to counter China's technological advancement or its anti-competitive, illicit, or undemocratic practices. Washington must, however, articulate a strategy that recognizes these challenges have the same root: the United States is engaged in a strategic competition with China and it must run faster. Running faster will require a course correction for the United States—a unified, consistent framework to guide the U.S. government's approach to key technology policy areas.

CRAFTING AN AFFIRMATIVE TECHNOLOGY POLICY AGENDA

The United States needs a national technology strategy not only to compete with China but to articulate and pursue its own technology policy goals and priorities. An overarching national approach could establish a technology policy agenda that affirms and capitalizes on America's key competitive advantages and is proactive in pursuing technologies that prioritize economic prosperity, protect national security interests, promote democratic values, and foster the betterment of society.

Unfolding advances in technological fields such as quantum computing, 5G wireless, or AI will spur immense economic opportunity.[24] A U.S. national technology strategy is needed to reap the economic power of emerging technologies, while also ensuring these advancements do not exacerbate existing

inequality.[25] A strategy is also needed to help define and solidify key national security and defense priorities.[26] America's economy is inextricably linked to its national security, and a unified, long-term technology strategy could help balance the country's competing interests, such as protecting critical technologies while also stimulating long-term economic growth.

The United States must articulate and advocate for a positive approach to technology use to counter the models advanced by autocratic nations such as China and Russia. As Center for a New American Security (CNAS) scholar Kara Frederick explained in her report "Democracy by Design," the United States "needs to be for a specific set of principles, and not simply play defense."[27] A strategy that establishes repeatable processes for ensuring that ethics and democratic values are enshrined in the country's development and use of emerging technologies could spur collaborative, multilateral efforts with allied and partner countries. The United States could also lead the way, partnering with both allies and competitors alike, to develop and apply innovative technological solutions to tackling global intractable challenges, such as climate change, food and water insecurity, and global health crises.[28]

The world will undergo profound technological change in the years and decades to come. The U.S. government needs a unified, coherent, repeatable, transparent, and defensible process for identifying and prioritizing technology investments to not only prepare for but shape these technological transformations. Step one is to define what a national technology strategy is and what it should do.

What a National Technology Strategy Is

A national technology strategy should be the guiding framework for the United States to plan, execute, and update its technology policies. The strategy must be a whole-of-nation approach—including human capital, infrastructure, investments, tax and regulatory policies, and institutional and bureaucratic processes—to preserve its current advantages and to create new ones. The overarching goal for this strategy should be to maintain the United States' standing as the world's premier technology power so that it can empower its citizens, compete economically, and secure its national interests without having to compromise its values or sovereignty.

America's S&T base will underpin the national technology strategy. This base comprises R&D investments, human capital, infrastructure, measures to safeguard technological advantage, technology norms and standards, and a regulatory framework that does not stifle innovation. Recommendations for strengthening America's S&T base comprise a major portion of this report.

This report does not propose a definitive list of priority technologies. Instead, it offers guidelines for how to go about that prioritization and provides illustrative examples. The goal of being the world's premier technology power does not mean that the United States will be at the leading edge in all technology areas. Attempting to do so would be prohibitively expensive and ultimately unrealistic: the United States' share of global R&D spending is much smaller than in decades past, advanced technological capabilities are increasingly diffused, and China can bring to bear a scale of manpower and resources that cannot be matched unilaterally.

A TECHNOLOGY PRIORITY SCHEMA

It is not necessary to be at the leading edge in all technology areas. The United States needs to be smarter about how it sets its technology priorities so that it can allocate its resources to greatest effect. The first step in setting cogent technology priorities is articulating a long-term vision. Where does the

United States want to be 20, 30, 40 years from now? That will determine the road map to execute the national technology strategy. Key to creating that road map will be a simple yet comprehensive schema to guide where and how the United States should allocate its resources. This schema consists of four categories:

1. *Leading-edge:* the technology areas where the United States must strive to have the most advanced capabilities in the world. These technologies are ones that form the backbone of the new digital economy or have the potential to upend the status quo. There are two subset categories. The first is *keystone technologies*—foundational technologies where cutting-edge capabilities afford tremendous economic or military advantages, such as microelectronics and AI. The second category comprises *disruptive technologies*—technology areas where breakthroughs have the potential to be game-changers, such as quantum computing.

2. *World-class:* the technology areas where the United States should strive to be among the world's best. This means being globally competitive across the board and having niche capabilities that set the United States apart. This grouping could include telecommunications and biotechnology.

3. *Fast follower:* the technology areas where the United States retains strong capabilities but can afford to not be among the world's best at the outset. One advantage this approach could bring is that the United States can observe the efforts of others and then focus its resources on areas that look most promising.

4. *Over-the-horizon:* this category comprises R&D investments, primarily in basic research, spanning the spectrum of technological disciplines. Doing so is critical to ensuring that the United States maintains the deep and diverse S&T base essential for technological leadership. It is also an insurance policy of sorts: technology forecasting is inherently difficult and important breakthroughs can occur in unforeseen areas and at unexpected times.

Setting technology priorities is a difficult and consequential process. Establishing principles to guide this decision-making will help to ensure effectiveness and consistency.

GUIDING PRINCIPLES FOR A NATIONAL TECHNOLOGY STRATEGY

A new comprehensive approach to technology policy is needed to address the scale and challenges of the current era of strategic competition. The framework for a national technology strategy should comprise six distinct but related principles.[29] The U.S. government needs to adopt an approach rooted in these qualities:

1. *Proactive:* U.S. leaders should determine what the country's technological goals and priorities are based on an agreed-to strategic vision, not the pronouncements or actions of competitors. Although there is quite likely to be overlap with the technology priorities of friends and foes alike and there will be a need to respond to specific technological developments by foreign actors at times, framing the effort this way ensures that technology development occurs in a manner consistent with U.S. goals and avoids undue copycatting.

2. *All-inclusive:* Policymakers should maximize the broad range of inputs that make up America's S&T base—including R&D spending, education, high-skilled immigration, tax policy, finance, infrastructure spending, and decades of experience and expertise within U.S. government labs, private companies, and academia in cutting-edge research—and treat technology areas as parts

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of an interrelated web, not stovepiped and independent disciplines.

3. *Whole-of-nation:* Lawmakers should understand that R&D and technological breakthroughs are not the sole domain of private industry. The federal government historically has played and should continue to play an important role in supporting and guiding technology development, especially basic research, and must be assertive in addressing occasional misalignments between what companies want to produce and what the U.S. government needs.

4. *Flexible:* Policymakers should craft a U.S. national technology strategy that is a mix of affirmative steps to boost competitiveness (such as investments in R&D, education, and supply chain resilience) and protective action (such as export controls and tariffs) to safeguard key advantages. The balance between the two should shift over time according to conditions and vary between different technological disciplines as conditions warrant.

5. *Iterative:* Government leaders must be prepared to regularly revisit the decisions, and their underpinning assumptions, that shape the national technology strategy with a transparent repeatable process that involves stakeholders from private industry and civil society. Technology forecasting is difficult and the global context for which the national technology strategy is crafted can change considerably in little time. The nation's technology priorities should shift accordingly.

6. *Multilateral:* America's leaders must work with allies and partners. The United States cannot effectively tackle most technology policies unilaterally; the requisite knowledge and capabilities are too diffused. Broad-based, proactive, and multilateral cooperation among like-minded countries is needed to maximize effectiveness.[30] The United States' network of alliances and partnerships is one of its greatest strengths and should be capitalized upon.

This schema for how to think about tech prioritization will guide policymakers as they craft the details for a national technology strategy. The guiding principles provide the underpinning qualities that will help to make the strategy as successful as possible. Before considering specific recommendations, the final element in creating a national technology strategy is understanding how the United States tackled technology strategies and industrial policies throughout history, as there are lessons that are relevant to today's strategic competition.

How the United States Competed: Past Technology Strategies

The United States has a rich history of planning and executing technology strategies. This section provides historical vignettes to highlight how the U.S. government harnessed technology policies to address critical geopolitical challenges. It also addresses critiques of technology strategy and industrial policy and what approaches are, and are not, suitable for the current economic, political, and societal environment. This section concludes with identifying six important lessons from past American technology policy approaches that are relevant today.

The current laissez-faire approach of minimal regulations and U.S. companies largely driving technology development is an outlier in American history. Governmental action that can be considered "technology strategy" dates back to the earliest days of the republic. Congress, for example, is empowered to "promote the progress of science and useful arts" with patent and copyright laws in the U.S. Constitution. Alexander Hamilton can be considered the founding father of American technology strategy with his treatises on tariffs, subsidies, and investments as the first secretary of the Treasury.[31]

William S. Knudsen, president of General Motors Corporation from 1937 to 1940, received a commission as a lieutenant general in the U.S. Army and was appointed in 1942 as Director of Production, Office of the Under Secretary of War. As part of a production-focused technology strategy, output of war materiel skyrocketed under his direction. (National Archives)

Since the 1980s, the U.S. government has been increasingly hands-off on economic and technology matters, largely letting the market take its course. By and large that has worked well due to America's overwhelming economic strength, military power, and unmatched technological capabilities. That dominance, however, is rooted in investments made decades earlier and is increasingly at risk due to underinvestment by the federal government in science and technology, human capital shortfalls, and a rising China in a new era of strategic competition. A course correction, in the form of renewed government involvement by setting a national technology strategy, is necessary to regain the initiative. Such a course of action is consistent with past U.S. policymaking.[32]

Beyond stimulating economic growth, government-led technology strategy helped to win America's most threatening wars. During the Civil War, the Union capitalized on its substantial economic advantage over the Confederacy by doubling down on expanding industrial capacity. The United States had employed a wide-ranging technology strategy during World War II with the simple objective to "produce war materials with little concern for such complications as international competitiveness, antitrust laws, or competing national objectives."[33] This policy was the reason why General Motors became the largest producer of war materials seemingly overnight.[34] U.S. R&D spending, combined with a military buildup, ultimately gave the U.S. military a significant technological advantage over Soviet forces by the end of the Cold War.[35]

THE LEGACY OF VANNEVAR BUSH

The driving force and intellectual architect of America's WWII and early Cold War industrial policy was Vannevar Bush, an engineering professor from the Massachusetts Institute of Technology, founder of the company Raytheon and eventual head of the Manhattan Project to build the atomic bomb. In 1945, Bush published "Science, The Endless Frontier," a report capturing lessons learned from five years of intensive collaboration among government, industry, and academia.[36] The report is a seminal one, making the case for the importance of basic research as the one and only source for critical new knowledge. In the letter to President Harry Truman accompanying the report, Bush closed by observing that "[s]cientific progress is one essential key to our security as a nation, to our better health, to more jobs, to a higher standard of living, and to our cultural progress."[37]

American manufacturing companies were essential in the creation and assembly of essential U.S. war materials in World War II, including M3 tanks. U.S. government-led technology strategies are critical to ensuring victory in America's most threatening wars. (Hulton Archive/Getty Images)

Bush left an indelible mark on 20th-century American scientific and technological achievements. His advocacy for basic research influenced R&D investments for decades; Congress created the National Science Foundation in direct response to "Endless Frontier"; and Bush's innovation to steer government funds not to government-run labs but to universities and private industry changed America's technological landscape and set the stage for innovations such as the transistor, early internet, and the global

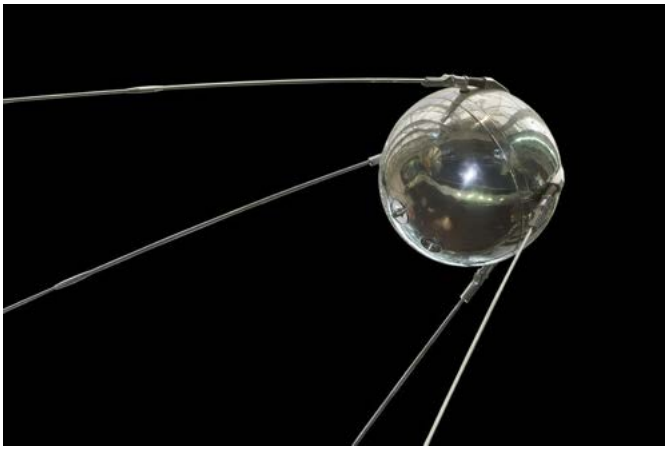
positioning system (GPS)—technological breakthroughs that continue to drive the American economy decades later.[38] More immediately, Bush set the stage for American competitiveness in the first postwar technology competition: the space race.

SPUTNIK MOMENT

In October 1957, the Soviet Union lobbed the world's first satellite into space, officially launching the U.S.-U.S.S.R. space race. A centerpiece of the Cold War, the space race catalyzed U.S. science and technology competitiveness and galvanized the American public in the decades that followed. Sputnik I led to a crisis of confidence among the American public, exacerbated by the Soviets' successful launch of Sputnik II and the failure of the United States' first satellite launch attempt.[39] For the American people, Sputnik called into question the country's technological competitiveness and instilled a fear that the United States was already behind in this novel space age, creating an environment conducive to remarkable transformations in the country's S&T base.

In the aftermath of Sputnik, the U.S. government created powerful new institutions, significantly increased its R&D spending, and created incentives for students to study STEM at U.S. universities. First, Congress created the National Aeronautics and Space Administration (NASA), a fusion of the National Advisory Committee for Aeronautics (NACA) and three national laboratories.[40] NASA was given a clear mission—to land a man on the moon—and a robust budget. [41] At NASA's peak, its budget accounted for nearly 4.5 percent of the federal budget.[42] NASA "dramatized the federal role in support of science and technology" during this period, and its work and research contributed to the creation of technologies such as GPS, LEDs, CAT scans, and artificial limbs.[43]

The U.S. government created ARPA—the Advanced Research Projects Agency (later renamed the Defense Advanced Research Projects Agency, or DARPA)—in February 1958 with a mission to prevent future technology surprises.[44] Like NASA, ARPA's impact extended far beyond the federal government. Its best-known and most influential work was creating the technical foundation for the internet, as well as contributing a wide range of technologies, including GPS, voice recognition, and stealth aircraft.[45]



The Soviet Union's launch of Sputnik I on October 4, 1957, spurred a decades-long competition between the United States and the Soviets. In response to the launch, the United States significantly increased its research and development spending, passed the National Aeronautics and Space Act, and created the Advanced Research Projects Agency. (Carlos Moreno Rekondo/Wikimedia)

In addition to new institutions, the Sputnik moment precipitated the passage of the National Defense Education Act (NDEA) of 1958, a bill influential in training a new generation of scientists and engineers.[46] The NDEA devoted large-scale federal funding to ensure "trained manpower of sufficient quality and quantity to meet the national defense needs of the United States."[47] The legislation legitimized the idea of federal funding in higher education, authorizing the first federal student loan program and providing funding for STEM and foreign language education.[48] Although interest groups had been advocating for federal investment in education for some time, Sputnik served as a catalyst for the NDEA's passage.[49]

The Sputnik launches also served as the impetus for an enormous increase in federal R&D spending. By the 1960s, the federal government was funding nearly 70 percent of U.S. R&D.[50] In fact, the U.S. government was spending more on R&D during this period than the rest of the world combined.[51] This massive government

spending was critical to establishing a vibrant tech and start-up community in the United States.[52] As Margaret O'Mara writes in her book The Code: Silicon Valley and the Remaking of America:

> *… in its celebration of the free market, the individual entrepreneur, and the miracles of a wholly new economy, the Silicon Valley mythos left out some of the most interesting, unprecedented, and quintessentially American things about the modern tech industry. … From the Bomb to the moon shot to the backbone of the Internet and beyond, public spending fueled an explosion of scientific and technical discovery, providing the foundation for generations of start-ups to come.*[53]

The transformations to the United States' S&T base post-Sputnik resonate to this day. U.S. policymakers in recent years have called for another "Sputnik moment" to galvanize government action and public involvement to tackle today's toughest challenges.[54] While Sputnik may be an imperfect analogy to describe the country's current position, its legacy provides important lessons for the United States as it faces a rising China and a growing number of global challenges.

COLD WAR INITIATIVES

Throughout the remainder of the Cold War, the U.S. government played a vital role in supporting and driving technological competitiveness. Through a variety of vehicles ranging from those oriented at enhancing broad-based S&T competitiveness, such as the Bayh-Dole Act or the Small Business Innovation Research (SBIR) program, to targeted industrial policy in key areas, such as SEMATECH's role in the semiconductor market, the U.S. government enhanced the country's innovation base and solidified its competitive edge.

The Bayh-Dole Act and the Stevenson-Wydler Technology Innovation Act, both enacted in 1980, as well as the Small Business Innovation Research program, were instrumental in creating a technology ecosystem conducive for successful partnerships between the federal government and the private sector. The Bayh-Dole Act gave universities, research labs, small businesses, and nonprofits the rights to any intellectual property resulting from federal research funding.[55] In its first 20 years, it generated a "tenfold increase in academic patenting" and "over 80,000 patents and 12,000 start-ups resulting from academic tech transfer."[56] The Stevenson-Wydler Technology Innovation Act, the first major U.S. law on technology transfer, stated that "technology transfer, consistent with mission responsibilities, is a responsibility of each laboratory science and engineering professional."[57] Under the act, federal agencies and research labs were required to create an Office of Research and Technology Acquisitions to streamline the process of identifying and transferring technologies with commercial potential to the private sector.[58] The U.S. government also supported private-sector innovation through the Small Business Innovation Research program. Created in 1982, the SBIR mandated that some federal agencies (those with extramural* R&D budgets in excess of $100 million) direct a share of their R&D budget to small businesses.[59] Congress reauthorized the SBIR in 1992 and, in parallel, established the Small Business Technology Transfer (STTR) program to accompany it.[60]

At times, the U.S. government played a more direct role in a key technology sector if it felt the country's competitive edge was at risk. In the mid-1980s, the U.S. semiconductor industry was struggling to compete against formidable Japanese firms.[61] America's share of global semiconductor production had remained steady at 60 percent for most of the 1960s and 1970s, but by the late 1980s it had fallen below 40 percent.[62] In response, the U.S. government partnered in 1987 with the newly established consortium of 14 U.S.-based semiconductor firms called SEMATECH (or "Semiconductor Manufacturing Technology").[63]

Over the next eight years, SEMATECH received approximately $870 million from DARPA, a contribution matched by industry participants.[64] By the mid-1990s, the U.S. semiconductor industry had bounced back and was once again a leader in the global market.[65] While it is difficult to measure SEMATECH's exact impact, it certainly contributed to the industry's recovery.[66] In 1992, the General Accounting Office found that SEMATECH had shown a "government-industry R&D consortium can help improve a U.S. industry's technological position by developing manufacturing technology."[67]

TECHNOLOGY STRATEGY AND THE STIGMA OF INDUSTRIAL POLICY

Technology strategy and industrial policy are largely synonymous if one considers that "industrial policy" is generally defined as actions by a country's leadership to develop, grow, or reorient parts or all of its economy to achieve a specific objective.[68] In recent decades, however, many American leaders have come to consider "industrial policy" a pejorative term. A common refrain among contemporary critics of industrial policy is that the U.S. government should not pick winners and losers, that it does not have the capacity to set the right priorities, and that such matters are best left to the free market.[69]

Prominent critics of industrial policy such as the economist Charles Schultze often focused on narrower interpretations of the concept, such as the misguided attempts to shield manufacturing jobs in declining industries and ill-informed government directives aimed at shaping the business activities of individual firms.[70] He concluded, correctly, that such interventions are fundamentally flawed. More recently, others have pointed to the market distortions and moral hazards that such government actions carry.[71] Such concerns are also justified.

This report does not propose that kind of government involvement. Rather, it is a case for the U.S. government to create a strategic national-level framework for technology policy by making the proper investments in R&D, education, and infrastructure, and by setting policies for areas such as taxes, regulations, and immigration that align with free market principles and comport with American values. Technology strategy from this standpoint is the kind of industrial policy that the United States has used to great effect and benefit for much of its history.

LESSONS FROM U.S. HISTORY TO MAXIMIZE COMPETITIVENESS TODAY

America's history of government involvement in the nation's S&T enterprise offers a guide for how to think about Washington's role in engaging with industry and academia in the current technology contest. Attitudes on the merits of government-led technology strategy are already starting to shift, with legislators from across the political spectrum proposing measures to boost American competitiveness and reduce foreign dependence in areas such as telecommunications, microelectronics, and critical minerals. There are five core lessons from the historical American experience with technology strategies that policymakers should bear in mind:

Lesson 1: The U.S. government's capacity to maintain a comprehensive and nimble S&T base requires deliberate long-term planning and sustained federal investment. While the shock of the Sputnik I launch was a catalyzing force for the United States and gave the government the political capital to launch new agencies and increase funding for R&D and education, the groundwork for the U.S. response was laid decades before.[72] NASA benefited from the work of its predecessor, NACA, and the provisions in the NDEA were long underway when it became law.[73] The U.S. government must recommit anew to sustained and long-term support for the country's S&T infrastructure to ensure that the foundation for American innovation is strong and comprehensive.

Lesson 2: The U.S. government can direct its technology investments and inspire the public to contribute to national priorities by establishing clear and attainable national objectives. President John F. Kennedy was unambiguous in his May 1961 address that the United States "should commit itself to achieving the goal, before this decade is out, of landing a man on the Moon."[74] This national goal not only provided direction for the federal government's research and investments, but galvanized the American public. U.S. political leaders should articulate specific objectives with measurable metrics for key technology sectors and explain how those goals will bolster American competitiveness and national security and boost economic growth.

In 1969, American astronauts Buzz Aldrin, Michael Collins, and Neil Armstrong became the first humans to walk on the moon. This accomplishment was the result of a clear objective set by the U.S. government that provided direction for its research and investments. (Courtesy of the National Aeronautics and Space Administration)

Lesson 3: The U.S. government's role in R&D investments is critical, but so is its method for allocating and overseeing this funding. Federal R&D spending post-Sputnik, particularly its support for basic research efforts, contributed to remarkable breakthroughs in a number of key technology areas. As O'Mara explains in her book The Code, however, how the government spent its money—"indirectly, competitively"—gave the tech community the freedom to "define what the future might look like, to push the boundaries of the technologically possible, and to make money in the process."[75] Significantly increased federal R&D investments, allocated through decentralized mechanisms that fund research at universities and in the private sector, can fuel American innovation without putting the government in a position of picking winners and losers.

Lesson 4: Government-led investments in research, education, and S&T infrastructure yield lasting economic and technological benefits. America's economic power and technological leadership today in areas such as the internet, AI, semiconductors, and precision navigation and timing are rooted in investments made in the 1950s, 1960s, and 1970s. More generally, R&D is a key driver of long-term economic growth.[76] As history shows, sustained federal government investment in science and technology research is foundational to American technological leadership and the U.S. government should once again provide adequate investments to ensure the country's competitiveness in the decades to come.

Lesson 5: U.S. government action is key to ensuring that technology diffusion throughout the economy maximizes innovative potential. U.S. government actions in the 1980s to promote technology transfers from the public to the private sectors—the Bayh-Dole Act, the Stevenson-Wydler Technology Innovation Act, and the Federal Technology Transfer Act of 1986—resulted in thousands of spin-off companies and greater innovation.[77] Lawmakers should periodically reevaluate these measures to ensure they remain relevant for the current context as well as explore new policies to further encourage technology diffusion, such as the proposed National Research Cloud that would provide access to needed compute and data resources to a much broader swath of American AI researchers.

Lesson 6: The U.S. government can effectively intervene in key technology industries by applying more direct, targeted policy measures at certain critical junctures. While the U.S. government typically applies broad policy measures toward its S&T base, there are instances in recent years where the United States has played a more direct role in specific industries. The U.S. government was instrumental in researching, developing, and financing the technologies necessary to win the space race. The government's involvement in SEMATECH in the late 1980s helped revitalize a declining U.S.

semiconductor industry. The U.S. government's standard practice toward its S&T investments should remain indirect and mostly hands-off. In special circumstances, however, the U.S. government must be willing to intervene more directly in a key technology sector to ensure sustained American competitiveness.

How the United States Should Compete Today

The United States is competing with China in technology with one hand tied behind its back.[78] While the United States has leading technology companies, the government is underperforming in its role as a critical catalyst of S&T innovation. The federal government has played a more active role in protectionist measures relating to Chinese tech in recent years, including export controls, investment screening, and executive orders banning Chinese firms, but the government has yet to bring to bear its substantial tools to help stoke the fires of American innovation.

Policymakers in Congress and the White House need to recalibrate U.S. government involvement in the country's innovation ecosystem to maximize advantages and opportunities and to successfully address the challenges that the United States will face in the global technology contest. The nature of this competition is fundamentally different from what America has faced since the 1940s. For the first time in nearly a century the United States confronts a strategic rival that is capable of overtaking it as the world's leading economic, military, and technological power, and one that is economically entangled with the United States. China is leveraging comprehensive state-directed efforts such as Made in China 2025, Standards 2035, the Belt and Road Initiative, and the Digital Silk Road to guide its technology development at home and push its goals of making Chinese technology and technology standards dominant worldwide.

Chinese President Xi Jinping and Russian President Vladimir Putin attend a meeting during the Belt and Road International Forum, an initiative aimed at pursuing dominance in a number of key technology areas. The United States must respond with policies that focus on research and development, patenting, and standard setting. (The Russian Presidential Press and Information Office/Wikimedia)

The hallmarks of these initiatives include strategic goals and plans backed with substantial financial resources for R&D, patenting, and standard setting. Neither the United States nor any of the tech-leading democracies has anything equivalent, setting the stage for an uneven competition where Beijing is better positioned to have the upper hand over the long term. This is not to say the United States should emulate China's top-down approach. Many aspects of China's approach, such as the creation and promotion of national champions; the coddling of inefficient state-owned enterprises; export subsidies, forced technology transfers, and other illiberal trade practices; and the lack of accountability and oversight are anathema to the American system.

At the same time, Beijing's policies have had impressive results. China is the world's largest trader, accounting for 12.4 percent of global trade in 2018.[79] China's R&D spending has grown at an average of 15 percent annually since 1998. It is on track to overtake the United States in total R&D spending by the mid-2020s and is at the forefront of foundational technologies such as AI, 5G, and quantum computing.[80]

The U.S. response has been largely protectionist and unilateral, focused on export controls, tariffs, and repatriation of manufacturing, while R&D spending remains flat as a percentage of GDP and policies to attract and retain high-skilled foreigners become increasingly restrictive. American policymakers must emphasize what is lacking so far: the proactive policies American policymakers can put in place to bolster America's ability to outcompete. To effectively compete with China, the United States needs a technology strategy for the 21st century and a new approach to multilateral cooperation and collaboration.

The United States has an unmatched strategic advantage over China in this technology competition: a global network of allies and partners. Harnessing this network for multilateral collaboration is critical to the success of a national technology strategy. The United States does not enjoy a monopoly over the technologies that will drive the 21st-century economy, but the United States also does not have to go it alone. By partnering with other tech-leading nations, the United States and its allies and partners can bring far more financial and human resources to bear in this competition than China can alone.

American and Australian officials sign a cyber agreement to create a cyber training range. This agreement is one of the many ways that the United States can partner with other tech-leading nations to develop better technology capabilities. (USCYBERCOM Public Affairs)

Opportunities for multinational collaboration on technology policy abound. The United States could look to existing groupings such as the Five Eyes, the National Technology and Industrial Base, and the Quadrilateral Security Dialogue to enhance such collaboration. There are also proposals to create new groupings: U.K. government officials have proposed a "Democracy 10" to tackle 5G and other technology issues; and former U.S. government officials have proposed alliance frameworks to tackle a range of technology policy issues.[81] A recent CNAS report by an international group of researchers lays out what countries should comprise such a grouping, how it should be organized and structured, how it should function, and what its top priorities should be.[82]

Recommendations

A strategy's success hinges on implementation. No expression of strategic direction is complete without actionable recommendations. As the initial framing document for a series of publications that will define and outline a U.S. national technology strategy, this report lays out the four pillars that comprise the actions necessary to execute it. The pillars are to *promote* America's ability to compete; *protect* key U.S. technological advantages; *partner* with allies to maximize success; and *plan* effectively to reevaluate and adjust the strategy as needed.

This section offers recommendations for each pillar. They include the highest priority actions U.S. policymakers should undertake to safeguard long-term U.S. technological competitiveness. It is by no means an exhaustive list. Rather, it is an opening salvo meant to underscore the scope and scale of the challenge, highlight the urgency with which the United States must act, and stimulate ideas for a broader set of necessary actions.

Taken together, these pillars and the recommendations that underpin them are guidelines for a 21st-century industrial policy. The American experience with industrial policy throughout its history shows that it is beneficial and necessary to have government involvement in technology development and that it is feasible to do so in a manner that encourages rather than constrains innovations by the private sector. The recommendations that follow are crafted with that spirit in mind and are the baseline for American success in the global technology competition.

PROMOTE AMERICA'S CAPACITY TO COMPETE

The U.S. government needs to take comprehensive and urgent action to lay the groundwork for long-term and comprehensive structural improvements to its science and technology base. There are four categories of recommendations to promote U.S. competitiveness:

1. Increase investments in research and development in the United States. While tech-leading countries around the world have increased their R&D spending, the United States has kept steady as a percentage of GDP for decades. The U.S. share of global R&D fell from 69 percent in 1960 to 28 percent in 2016.[83] During that period, the share of R&D investments by the federal government shrank by more than half, meaning that private industry is now driving R&D to a much greater extent. In response, Congress should act by:

- Raising federal government spending on R&D to at least 2 percent of GDP by 2030, up from around 0.7 percent in 2020. This spending is critically important to maintaining long-term capacity for technological leadership and innovation. The U.S. government remains the largest funder of basic research, which is foundational to game-changing technological achievements.[84]

- Promoting an increase of total national (public and private) R&D expenditures to at least 4.5 percent of GDP by 2030, from under 3 percent in 2020, to keep in line with other leading technology nations. Tax incentives, targeted grants and contracts, and prize competitions all serve to stimulate private-sector investments.

2. Develop and execute a national human capital strategy. U.S. policymakers need to ensure that the American workforce has the requisite educational and training resources to respond to rapid shifts in needed skills and knowledge in response to a fluid technology landscape. This ability would be a key determinant of success in the global technology competition. Congress must provide sustained attention to foundational education, ongoing skills training, and increased support of research capabilities at U.S. colleges and universities. Legislative actions are needed to empower the American public by:

- Increasing public- and private-sector science, technology, engineering, and math education and skills training to grow and sustain America's S&T workforce.

- Increasing funding opportunities for university researchers to promote high-skilled talent retention in academia. Growing numbers of academics pursuing careers in private industry, often due to funding constraints and the lure of higher salaries, hinder overall capacity to train future generations of STEM-focused talent.[85] Federal grants to academia decreased from their 2011 peak of $45.5 billion to $40.9 billion in 2017.[86]

3. Attract and retain the world's best and brightest S&T talent. The geostrategic competition is very much one for global talent. This facet of the competition is a true zero-sum game: every foreign researcher who does not come to the United States to live, work, and innovate is a boon to another country. Congress and the White House should work together to change U.S. immigration policies to reflect this reality by:

- Raising the cap for H-1B visas and removing the cap for advanced-degree holders entirely. International talent remains a critical backbone of the country's technological ecosystem. U.S. technology firms currently rely heavily on temporary-hire foreign workers to fulfill critical shortages in STEM occupations.

- Amending the Department of Labor Schedule A occupations list to include high-skilled technologists. Doing so would streamline the permanent residency sponsorship process for employers.

- Creating a new program that couples visa grants to 10-year open-market work commitments. This approach would attract foreign students already highly predisposed to remain in the United States, target specific technology-related disciplines, and eliminate the cost and uncertainty of extending job offers to qualified foreign nationals by removing employer sponsorship requirements.[87]

4. Expand access to S&T infrastructure and resources. To set up America's human capital for maximized success, the United States must invest in expanding and easing access to the country's digital infrastructure. Congress should act by:

- Establishing a National Research Cloud that pools government-owned and -funded compute and data resources, modeled on the proposal by the Stanford Institute Human-Centered Artificial Intelligence.[88] The National Security Commission on Artificial Intelligence made a similar recommendation in its November 2019 Interim Report.[89]

- Improving digital infrastructure in America's underserved areas. Small cities, towns, and rural areas in the United States suffer from a digital divide that hinders economic development outside of the main U.S. technology hubs. The dramatic shift in how many Americans worked and attended school during the COVID-19 pandemic underscored the importance of the need for robust broadband to enable a restructuring of the U.S. research community. Private 5G networks, for example, show promise as a way to bring broadband to underserved parts of the country.[90]

PROTECT CRITICAL U.S. TECHNOLOGICAL ADVANCES

Safeguarding America's edge in key technology areas and countering unwanted tech transfer is essential to enacting a successful national technology strategy. Doing so effectively will require a mix of protective and proactive measures. There are four main lines of effort to secure America's technological edge:

*1. Reframe the goal of export controls***.** Export controls should be crafted and enacted with relevant allies in most cases because the United States rarely has the clout or capacity to act effectively on its own. They should also be used sparingly—export controls are most effective when targeting a foreign actor's technology indigenization efforts and largely ineffective over the long term as a tool of economic statecraft such as sanctions. An example of what export controls under these tenets would look like is:

- Enacting multilateral export controls on semiconductor manufacturing equipment. The United States and its allies have no strategic interest in China indigenizing cutting-edge semiconductor design and fabrication. Semiconductor-related controls should therefore focus on the tools and know-how needed to manufacture them; not the chipsets themselves, the majority of which are commodity items. Doing so preserves important revenue streams for U.S. companies, reduces incentives for China to pursue indigenization, and preempts unfair competition with Chinese mercantilist industrial policies.

2. Collaborate with partner countries on investment restrictions. The U.S. government has implemented the final rules for the Foreign Investment Risk Review Modernization Act that expanded the jurisdiction of the Committee on Foreign Investment in the United States (CFIUS), an interagency committee that reviews certain foreign direct investment transactions. Under the Trump administration, the U.S. government increased the use of CFIUS to undo or block transactions deemed a national security threat. At times, these actions appear devoid of strategy and lack coordination with allies, such as the unilateral actions against the Chinese app TikTok.[91]

- The White House should focus on engaging with allies and partners to set harmonized restrictions to address diverging investment screening regimes.

3. Counter and mitigate unwanted technology transfers. American adversaries, China in particular, seek access to important U.S. technologies and related know-how through a range of licit and illicit actions. The scale of the theft is such that it costs the United States hundreds of billions of dollars every year. There are myriad ways the U.S. government can help to stem this damaging activity, such as by:

- Providing more cyberdefense support to small firms. Small and medium businesses in general are more vulnerable to cyberattacks.

- Authorizing consular officials to act on risk indicators for espionage to screen out high-risk individuals before they arrive. America's diplomats often have a good understanding of risk factors beyond those they can justify visa denials with. In an important step, the Trump administration announced a plan to deny visas for Chinese nationals with direct ties to universities affiliated with the People's Liberation Army and charged four researchers already in the United States with visa fraud for lying about such affiliations.[92]

- Improving collaboration between U.S. counterintelligence experts and leaders of academic institutions. This partnership should include information sharing and training on counterintelligence, and research integrity and due diligence training on possible malign end uses of multiuse technologies. One action should be to reestablish the National Security Higher Education Advisory Board, a forum set up in 2005 to foster communication between universities and the national security community on issues such as counterintelligence threats.

4. Restructure critical supply chains. Many of America's supply chains are dangerously brittle and present vulnerabilities that must be addressed. Doing so will be expensive, complex, and time-consuming. To guide decision-making on what supply chains to prioritize and how to proceed, officials from the departments of Commerce, Defense, and State, the White House, and the intelligence community, in cooperation with Congress and private-sector stakeholders, should initiate a three-part process for:

- Diversifying and securing key supply chains. This includes identifying the supply chains where those vulnerabilities pose an unacceptable risk to U.S. national security, economic security, and core necessities; auditing these essential supply chains in conjunction with relevant industry leaders; and crafting and executing a strategic plan to disentangle them.

PARTNER WITH U.S. ALLIES AND PARTNERS TO MAXIMIZE SUCCESS

America is gifted with a remarkable network of allied and partner countries. The United States should capitalize on this advantage by partnering with these countries to:

1. Enhance bilateral and multilateral research efforts. Adequate R&D investment is critical to sustaining U.S. technological competitiveness. U.S. federal R&D spending has dropped since the end of the Cold War, while the rest of the world's spending has steadily risen.[93] The United States and allied nations can expand joint R&D efforts by:

- Establishing international R&D centers to spur multilateral collaboration on basic and applied research. While issues surrounding IP rights and technology transfer would have to be addressed, multilateral R&D efforts would allow for cost sharing and increased interoperability across countries, as well as the alignment of complementary knowledge and experience.[94]

2. Create a human capital network to foster multilateral collaboration. A robust talent pipeline is fundamental for sustained U.S. technological competitiveness. Restrictive high-skilled immigration policies and other bureaucratic obstacles have weakened America's human capital base. The United States and allied countries can foster cross-border collaboration, such as by:

- Creating a network for multilateral collaboration where scientists, technologists, and engineers from allied and partner countries can travel, work, and live in participating countries.[95] These talent exchanges could amplify and enhance collaborative research efforts in both the public and private sectors and promote the exchange of ideas across borders.[96]

3. Codify norms for technology use. Technology-leading nations will have outsized influence in shaping the norms and principles for how technologies should and should not be used. The same technologies that can be used to communicate; to extract valuable insights from data; and to enable discovery and breakthroughs can also be used to control and distort information; to monitor, isolate, and suppress individuals and groups; and to disrupt critical infrastructure. The United States should counter the illiberal use of technology by:

- Leading like-minded countries on setting norms for the responsible use of technologies consistent with liberal democratic values. This should include foundational and emerging technologies and their broad application such as for AI, surveillance technology, and cyberspace.

4. Reclaim the integrity of international standard-setting. China is pursuing a comprehensive strategy to have Chinese-origin technologies be the foundation for global technology platforms and reduce its dependence on foreign intellectual property and standards. The way the Chinese government links standardization with mercantilist industrial policies is at odds with the purpose and spirit of international standard-setting. To preempt further degradation of international standard-setting, the United States with other tech-leading democracies should focus on:

- Preserving the integrity of global standard-setting by making resources available for companies to send full delegations and submit the broadest possible portfolio of technologies to standard-setting bodies for consideration, and to call for reforms of the bodies to prevent bloc voting.

- Taking a more involved role in global standard-setting. The U.S. National Institute of Standards and Technology issued a report with recommendations for AI standard-setting that could serve as a framework for engagement on all standard-setting efforts. The recommendations include building stronger ties with stakeholders in foreign governments and private industry and taking leadership roles in setting standards such as by convening or administering consensus groups.[97]

5. Establish a network of like-minded countries to collaborate on technology policy. Technology policy coordination among like-minded countries is often sporadic and disjointed. The United States should initiate deeper international collaboration on key technology policy issues with allied countries. This kind of collaboration could serve as a mechanism to foster this collaboration and could come in a number of different forms, including:

- Creating a multilateral technology alliance with a core group of like-minded countries to collaborate on technology policy.[98] A formal grouping of allied countries could focus their efforts on collaborative research on next-generation technologies, securing and diversifying supply chains, protecting critical technologies, and cooperating on international standard-setting and norms creation.[99]

PLAN FOR REGULAR STRATEGY UPDATES

The rapid and unpredictable nature of technological change means that the national technology strategy will require frequent reassessment. While the strategic objective—ensuring that America preserves its standing as the world's premier technology power to safeguard its economic competitiveness and national security—will remain the same, the elements that drive the strategy will be dynamic. Sound strategy requires adapting to changing conditions and adjusting elements of the strategy accordingly. There are three broad actions for the U.S. government to take to ensure that the national technology strategy remains relevant for a fluid context:

1. Review technology goals and their underpinning assumptions regularly. Once-promising technologies may lose their luster, tactical objectives may change, competitors can achieve technology surprise, and unforeseen opportunities could present themselves. These are some of the many reasons why a technology strategy requires updating. The U.S. government should ensure it is well-positioned to change tack by:

- Creating a repeatable and transparent process to update technology priorities for the national technology strategy and specific strategies for foundational technology areas such as AI, quantum science, semiconductors, and wireless telecommunications. Details on how to do so will be part of a forthcoming report in this series on how the U.S. government should be structured to craft, implement, and maintain a national technology strategy.

2. Maintain multistakeholder input. A national technology strategy is a whole-of-nation effort that requires buy-in and participation from stakeholders in government, private industry, academia, and civil society. Congress and the White House should ensure the long-term viability of the strategy by:

- Committing to ongoing engagement between the public and private sectors and civil society. Representatives from each stakeholder group should engage in regular issue-specific working groups, such as for 5G spectrum sharing or AI safety standard-setting, to discuss opportunities and challenges for executing the strategy, and be empowered to propose and act upon solutions and initiatives.

3. Bolster U.S. capabilities for assessing technology development and trends. Minimizing the risk of technology surprise and anticipating change strengthens strategy. The federal government and elements of the private sector already have pockets of excellence in relevant disciplines. The U.S. government can minimize the risk of uncertainty by:

- Establishing and expanding permanent technology analysis capabilities. The national technology strategy effort should emphasize horizon scanning, a technique designed to help detect change and discern trends; net assessments, a framework for long-term comparative assessments of trends and risk; and technology forecasting, a methodology for anticipating the features and functions of future technologies.

Conclusion

In this era of multifaceted strategic competition, the technology component may prove most consequential. Technology leadership by the United States and like-minded countries is imperative to promoting economic competitiveness, maintaining military strength, and safeguarding liberal democratic values. An ascendant and increasingly assertive and illiberal China poses a direct challenge. So far, the United States and its allies are failing to rise to the occasion: their responses have been slow, disorganized, fragmented, and often ineffective.

America must course-correct. Continuing to muddle along all but ensures China's eventual technological primacy, placing the United States on a glide path to mediocrity. This is an unacceptable and avoidable outcome.

U.S. policymakers in the White House and Congress must spearhead the crafting of a U.S. national technology strategy to regain the initiative and set the United States on course for success. This strategy should be a mix of proactive, affirmative, and protective measures to boost American competitiveness and secure key technological advantages. Engagement with and participation of industry and allied and partner countries alike is critical.

The United States enjoys considerable advantages over China with its world-class companies and universities, its long history of innovation, and its network of allies. But there are many areas in its S&T base where it is beginning to fall short. Now is the time for urgent action. The United States needs a comprehensive, long-term national technology strategy to get back on track and outcompete.

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