



# Competing in the Next Economy

The New Age of Innovation



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# Competing in the Next Economy

Just over 15 months ago, the Council on Competitiveness launched the National Commission on Innovation and Competitiveness Frontiers—in the firm belief that the nation's long-term growth in productivity and inclusive prosperity requires placing ever more attention on innovation to confer competitive advantage.

And while the United States has stood apart from the rest of the world during the past half century or more in its record of sustained innovation, across industries old and new, and through the ups and downs of economic cycles, the nation today faces realities and imperatives—some very new, some with the nation for a long time—transforming the context for continued innovation leadership:

- Other nations are replicating the structural advantages that historically have made the United States the center of global innovation;
- Many nations are developing their own, distinctive innovation ecosystems;
- The nature of innovation is changing—becoming dramatically more interconnected, turbulent and fast-paced;
- New research and business models are emerging, allowing someone to imagine, develop and scale a disruptive innovation independent of traditional institutions;
- Despite the growth of America's innovation-based economy, not every American has been brought onto the country's innovation team.

The National Commission was formed as a multi-year leadership movement to face these challenges at home and coming from abroad; to plan for the nation's long term success; to recommend action steps to put in place the talent, capital and infrastructure necessary to increase U.S. innovation capacity and capability for the future.

Comprised of 60+ National Commissioners—from industry, academia, labor and the national laboratories—the Commission has over the past year worked to develop its first report to the Nation—a “living” and evolving set of recommendations that will continue to grow in the coming years:

- On January 16, 2020, the Commission Community comprised of 200+ diverse innovation stakeholders from nearly all major sectors of the economy and regions of the country—including Commissioners, Advisors, Outreach and Engagement leaders, and members of four policy Working Groups—gathered at Arizona State University to map out the year's priorities and goals along a set of major themes:
  - Developing and Deploying at Scale Disruptive Technologies
  - Exploring the Future of Sustainable Production and Consumption
  - Optimizing the Environment for National Innovation Systems
  - Unleashing Capabilities for Work and Entrepreneurship

## National Commission on Innovation and Competitiveness Frontiers

### National Commissioners

60+ distinguished leaders from industry, academia, national laboratories and other critical stakeholder groups, including the Commission Co-Chairs:

**Dr. Mehmood Khan**  
Chief Executive Officer  
Life Biosciences, Inc.

**Mr. Brian T. Moynihan**  
Chairman and Chief Executive Officer  
Bank of America

**Dr. Michael M. Crow**  
President  
Arizona State University

**Mr. Lonnie Stephenson**  
International President  
IBEW

**Ms. Deborah L. Wince-Smith**  
President & Chief Executive Officer  
Council on Competitiveness

**Dr. Thomas Zacharia**  
Director  
Oak Ridge National Laboratory

### Advisory Committee

Three dozen+ multi-sector innovation leaders supporting the National Commissioners and guiding the Working Group agendas.

### Outreach & Engagement Committee

Two dozen+ strategic communications, media and government affairs leaders supporting the creative education, advocacy and communications plans for the National Commission.

### Working Groups

150+ innovators and leaders—from all sectors of the economy and across the entire country—brainstorming and developing actionable policy recommendations for the National Commission.

1. **Developing and Deploying at Scale Disruptive Technologies**
2. **Exploring the Future of Sustainable Production and Consumption**
3. **Optimizing the Environment for the Nation's Innovation Systems**
4. **Unleashing Capabilities for Work and Entrepreneurship**

- Following this Commission Community Launch conference and the onset of the COVID-19 pandemic, the Council and the Commission's four Working Groups—each led by a distinguished group of co-chairs—pivoted dramatically, built quickly a new way of collaborating, and endeavored non-stop between March and November 2020, in nearly 100 virtual workshops, to create, debate, refine and suggest hundreds of potential recommendations both for the Commission's mid-year report and its first annual report.

Of the hundreds of suggested recommendations, this 2020 annual report lays out 50 priority recommendations emerging across the four Working Groups because they are: (1) urgent—failure to act could create serious consequences for the United States;

(2) strategic—they are fundamental to U.S. economic security, as well as national security; and (3) pivotal—they could play a prime and determining role in the scope and rate of U.S. innovation.

**The bottom-line is simple—to compete in the next economy requires playing a new innovation game, one whose goal is to boost U.S. innovation tenfold: 10x.**

This is the call-to-action from the Council on Competitiveness and its National Commission on Innovation and Competitiveness Frontiers—for local, state and national policymakers to come together with the private sector to focus in a bold and transformational way on all efforts to optimize the United States for a new, unfolding, challenging innovation reality.

# Key Recommendations from *Competing in the Next Economy*

## A New Innovation Age Calls for a New Innovation Game

### 10x: Leadership and National Strategies for Innovation

1. Establish the White House National Competitiveness and Innovation Council (NCIC)—and parallel State Competitiveness and Innovation Councils—to create a national vision for U.S. competitiveness and innovation in the 21st century global economy, and integrate policy development across federal departments and agencies in this domain.
2. Build a whole-of-nation strategy for developing and deploying critical dual-use technologies that will shape the industries of the future, national security and global grand challenges—including advanced microelectronics, advanced computing (supercomputing, quantum, artificial intelligence), biotechnology, advanced materials, climate, etc.
3. Establish the National Innovation Radar Initiative, a coupling of innovation and intelligence assessment.
4. Establish a new Technology Statecraft Initiative and International Innovation Corps.
5. Secure supply chains critical to U.S. innovation, national security and economy growth.
6. Establish regulations, government procurement policies, and reforms in antitrust and competition policy to support the industries of the future.

### 10x: Increasing the Number of Innovations Developed in and Deployed by the United States

1. Keep the U.S. corporate tax rates competitive with EU and OECD nations, and include corporate pass-through entities in the Section 1202 exclusion, increasing asset limits to \$100 million.
2. Restore federal research and development (R&D) investment to 1960 levels of two percent of GDP.
3. Establish a new, non-profit American Innovation Investment Fund with initial public-private capitalization of \$100 billion.
4. Expand venture capacity nationwide, extend Treasury small business programs to encompass bank loans and private investors, allow equity investments into federal small business programs, and develop preferential rates for veterans and other underserved populations.
5. Establish new federal and state SBIR phase III grants to bridge the valley of death.

### 10x: Increasing the Speed at Which the United States Innovates

1. Establish the U.S. Digital Infrastructure Access and Inclusion Initiative.
2. Drive deployment—by federal, state and local governments—of new technologies that make infrastructure smarter, safer, more sustainable, more efficient, and more responsive and resilient.
3. Extend the mission of national labs to encompass economic competitiveness and permit co-funding with private sector partners.
4. Expand access to and public-private financing for shared research institutions and industry-led pilot demonstration projects.
5. Establish new sustainability curricula, innovation consortia, the “Patents for Planet” program, and new tax incentives or sustainability investments.

### 10x: Increasing the Number and Diversity of Americans Engaged in Innovation

1. Ensure all federal, state and local programs and investments in innovation capacity and education address the access, diversity and inclusion of minorities and women—with a goal to increasing their participation tenfold.
2. Redesign federal economic development programs to support innovation building capacity, eliminating outdated grant criteria and duplicative funding by adopting innovation metrics and performance standards for new block grant programs.
3. Conduct through State Competitiveness and Innovation Councils regional innovation mapping and assessments for building future innovation capacity.
4. Realign federal, state and local workforce development programs and training to enable a highly skilled, digitally competent, innovation workforce beginning at the junior and high school levels.
5. Launch new community-based public-private partnerships to support students and entrepreneurs, by expanding invention and entrepreneurship curricula in pre-K through higher education—with a goal to retain and grow regional innovation capacity.
6. Establish multidisciplinary engineering innovation centers and ecosystems in communities of dire economic and social need.

# The New Age of Innovation

Innovation—the advancement of technology and its application—is the engine of economic and productivity growth, a key to national security, and the driver of long-term improvements in living standards. And, more than any country on Earth or in history, the United States has been the greatest driver and economic beneficiary of technology-based innovation, leveraged in a culture of entrepreneurship and resiliency.

In the late 19th century and spanning decades into the next, U.S. inventors and entrepreneurs in agriculture, rail, oil, steel, and electricity—any many other sectors—launched the Industrial Age in America, turning the country into an industrial powerhouse, laying the foundation for a manufacturing sector that provided middle class jobs for millions of Americans. American innovations in vehicles and aircraft technology revolutionized transportation, changed the geographic face of the country, and opened the world wider for travel and commerce. American innovators have led the digital revolution since its beginning a half century ago, unleashing a new Digital Age of computing, communications, and information mobility—disrupting industries and business models, changing society and culture around the world, and creating enormous new wealth.

This continuum of invention and innovation has delivered prosperity and rising standards of living to Americans, and propelled the United States to global geopolitical leadership and the role model for the free world. Our engine of innovation has created the

largest economy in the world, jobs for millions of workers, cures for diseases and better health, a cross-country communications network and highway system that brings American society together, rising quality of life—comfort and convenience—across numerous dimensions from housing to transportation, a vast array of consumer products and services, the energy to power the country, and an abundance of food to feed the world.

## **Now, in the third decade of the 21st century, America has entered a new Age of Innovation.**

Humanity is in the midst of the convergence and acceleration of the greatest revolutions in science and technology. A new phase of the digital revolution—characterized by vast deployment of sensors, the Internet of Things, and artificial intelligence—is making our physical world smart and generating the abundance of big data that is providing unprecedented levels of insight in nearly every domain and systems optimization at every scale. Biotechnology and gene-editing have given humans the tools to manipulate the very “code of life,” nanotechnology the power to build things from the atom up, and autonomous systems to work without human hands, and watch the world and react without a human’s senses or intervention. Advanced computing, the big data revolution, and machine learning are accelerating research and transforming the tools of innovation, which will further propel discovery and new developments to new heights.

Each of these technologies and the innovations emerging from this deep ferment are just beginning to reveal their massive power and promise. They have numerous applications that cut-across industry sectors, society, and human activities. Each is revolutionary, each is game-changing in its own right. But they are now converging on the global economy and society simultaneously, creating a new age of unparalleled knowledge and vast technological power—a new Age of Innovation—with profound implications for individuals, companies, for societies, nations, for the global community, and for U.S. economic and national security. These innovations bursting forth from these powerful new technologies are disrupting industries and business models around the globe, shifting labor markets, shaping the future, and altering the patterns of society and many dimensions of our lives.

These technology-driven innovations also hold the potential to create solutions for some of humankind's greatest challenges—providing adequate food and clean water for the world's growing population, developing therapies to improve health and cure diseases, providing the clean energy needed to drive economic opportunity in developing and underdeveloped countries, and mitigating climate change and environmental problems that threaten our planet. New technology-based tools will open greater access to learning everywhere, further democratizing innovation and its benefits globally.

# America at the Crossroads

**At the same time the United States faces an unprecedented opportunity for progress, it also must confront a set of new competitive realities.**

New knowledge, new technological advancements, and the capital and skills needed to transform this knowledge and technology into innovations, products, and services for the world are now all highly mobile—and more than ever before in history, many countries around the world have access to any of these resources. As result, game changing technologies and innovations now originate almost anywhere, and nations around the world seek to leverage these resources for global competitive advantage and economic gain. Among these nations, a rapidly strengthening China seeks global technology leadership as part of its quest to become the world's economic, military, and geopolitical leader and shaper of the foundational rules for the “next” global economy.

U.S. leadership in technology-based innovation and our long-term competitiveness are under threat. As a nation's ability to innovate becomes ever more fundamental to its competitiveness and economic success, the very foundations of the U.S. capacity and capability in science and technology are eroding. There are deficiencies in the U.S. innovation engine, and barriers in developing and scaling new technologies. And, the United States has entered the third decade of the 21st century with too few of its citizens equipped with the knowledge, skills, and opportunities to participate and thrive in an ever more innovation-driven economy.

**How the United States and its leaders respond to the duality of this new age—unprecedented prospect for progress and prosperity on the one hand, and clear and present dangers at home and abroad on the other hand—will have profound implications for generations to come. If United States does not mount a strong all-of-nation response to these opportunities and new competitive realities at home and from overseas, if we fail to make needed investments in our people and future, our nation's fundamental capacity to grow its economy, create jobs, maintain national security, solve societal challenges, and provide a social safety net will continue to erode, and our geopolitical leadership will be at increasing risk.**

# 10x: A Bold and Transformational Goal

## Out Imagine and Out Innovate to Out Compete

To ensure our economic and national security, our geopolitical leadership, our place as the world's beacon of progress and problem-solving, and our position as the most prolific innovating nation on Earth, we must have world-leading capabilities; we must step-up our game in science, technology, and innovation; and we must field a growing, more diverse team of Americans involved in our innovation economy.

The Soviet Union's successful 1957 launch of Sputnik 1, the world's first artificial satellite, created a crisis and looming threat to American technology and military leadership. In response, in 1961, in an address before a special joint session of Congress, President John F. Kennedy challenged the Nation with the ambitious and audacious goal of putting an American on the moon, and returning his citizen safely to earth before the end of the decade. The goal galvanized the country. More than 20,000 industrial firms and universities mobilized.<sup>1</sup> The President inspired young Americans to help the Nation win the Space Race, and they fired off hobby rocketry, and pursued their science and math studies with new vigor.

Now facing threats of even greater scope and scale—and poised to take advantage of once unthinkable and unprecedented technology-based opportunities to kickstart a new era of U.S. productivity and economic growth, security and rising living standards, higher quality of life, and prosperity for all our citizens—the leadership of the National Commission on Innovation and Competitiveness Frontiers challenges the Nation with a new, ambitious and audacious goal.

<sup>1</sup> Fact Sheets, NASA Langley Research Center's Contributions to the Apollo Program, <https://www.nasa.gov/centers/langley/news/fact-sheets/Apollo.html>.

# The Goal: Achieve a 10x Increase in the U.S. Rate of Innovation

To achieve this goal, the United States must:

- **Increase the number of innovations we develop and deploy**
- **Increase the speed at which we innovate**
- **Increase the number and diversity of Americans engaged in innovation**

The National Commission believes the 10x goal is achievable. Why? Though unanticipated in December 2019 when the National Commission launched its 2020 agenda at the National Competitiveness Forum, the COVID-19 pandemic has paradoxically revealed a microcosm of what is possible, demonstrating that innovation, scaling, and massive transformation can occur on accelerated timelines previously inconceivable. Innovators prototyped personal protective equipment (PPE) and computer apps in hours or days, and they developed and tested—and are ready to deploy—vaccines in months instead of decades. Manufacturers shifted to new product lines in weeks, companies that deliver to the home scaled their industries' workforces by cutting hiring times from weeks to days and hours, medical and scientific journals began receiving a hundred or more submissions a day, and telehealth has scaled. In the United

States, prior to the pandemic, about 15 percent of the U.S. workforce worked at least one day per week at home.<sup>2</sup> By May 2020, half the U.S. workforce was working from home.<sup>3</sup> These are the kinds of transformations that can take years or decades to unfold, but they have happened—and continue to happen—right before our eyes. Imagine if we could operate with such speed and agility across the entire economy and country on a consistent basis.

In addition to our scientists and engineers, vast numbers of Americans that may not think of themselves as innovators can contribute to achieving the 10x goal:

- Entrepreneurs with new ideas and business models;
- Artists and designers who shape our products;
- Business managers who guide new innovative start-up companies;
- Authors and film-makers creating new worlds to enchant and developers making games to engage millions of people around the world;
- Fashion designers creating innovative apparel with functional fabrics;

2 Table 3. Workers Who Worked at Home and How Often they Worked Exclusively at Home by Selected Characteristics, Averages for the Period 2017-2018, Economic News Release on Job Flexibilities and Work Schedules—2017-2018, Bureau of Labor Statistics, September 24, 2019.

3 COVID-19 and Remote Work: An Early Look at U.S. Data, Erik Brynjolfsson, John J. Horton, Adam Ozimek, Daniel Rock, Garima Sharma, Hon-Yi TuTe, NBER Working Paper No. 27344, June 2020.

- Social scientists and cultural anthropologist partnering with innovators to create solutions for other cultures;
- Students acquiring a science and engineering education dreaming about what they will create and mentors showing them the way;
- And so many more.

During the COVID-19 pandemic, numerous Americans who did not consider themselves innovators have innovated—from fashion designers making PPE, to restaurant owners who designed and deployed new ways to safely prepare and deliver meals.

We must think broadly about innovation—products, processes, services, business models, solutions to problems, and more. For example, Uber reimagined and democratized “taxi service,” creating a new ride-sharing ecosystem, transforming personal mobility around the world in less than a decade, and growing to \$65 billion in bookings in 2019.<sup>4</sup> The McDonald’s brothers innovative efficient restaurant kitchen design launched a \$160 billion American icon and became the global model for fast food restaurant franchises. A young filmmaker’s creative and innovative Star Wars universe has entertained people around the world to the tune of \$70 billion, and transformed the film industry.<sup>5</sup> In 2004, that filmmaker, George Lucas, and his Industrial Light and Magic were presented the National Medal of Tech-

nology and Innovation, the Nation’s highest honor for achievements in technological innovation, bestowed by the President of the United States on America’s leading innovators.

**This first report from the National Commission—which reflects major findings from 10 months of work by nearly 300 geographically and sectorally-diverse innovation stakeholders (including a major launch conference at Arizona State University in January 2020 and nearly 100 dialogues between March and October 2020)—offers a snapshot of the competitive landscape, its threats and opportunities compelling us to action, and a vision about new leadership for achieving this bold 10x goal.**

**The Commission presents in December 2020, with a new Administration poised to assume national leadership in 2021, an initial series of recommendations for increasing the number of innovations, the speed of innovation, and the number of Americans innovators—first steps on a new pathway it believes will lead the United States toward meeting the goal of a 10x increase in its rate of innovation.** Over the next 2-3 years, the Commission will release additional recommendations on other critical aspects of the challenges we face, for example, the disruptions brought about by automation and the transforming world of work, the need for a new energy paradigm for a net-zero carbon world, international trade and

4 Uber 2019 Annual Report.

5 [https://en.wikipedia.org/wiki/Star\\_Wars](https://en.wikipedia.org/wiki/Star_Wars).

It seems to be a law of nature, inflexible and inexorable, that those who will not risk, cannot win.

**John Paul Jones**

American Naval Revolutionary War Hero

technology policies that respond to the new competitive realities, widening access to capital for U.S. innovators, and the sustainability of production and consumption.

The quest to achieve this goal, and navigating and succeeding in this new and ever-shifting environment, will require the United States—its governments, its companies, its colleges and universities, its labor unions, its national laboratories and research enterprises, and its people—to experiment, take risks, and try new things. Some will be big successes, many will fail. But it would be a mistake to let those failures become overly politicized and drive us to risk avoidance. If we will not take risks, we cannot make progress. And should our new strategic competitor achieve its goals, freedom and democracy at home and abroad will face ever greater risk.

Since the founding of the United States, the American experience has always involved pushing beyond perceived limits and frontiers and taking risks—the exploration of the North American continent; the exploration of space, and opening moves for its habitation and industrialization; and the risky bets made by early U.S. industrialists and our high-tech entrepreneurs that, ultimately, shaped the 20th and early 21st centuries. Mistakes have been made, set-backs have occurred, and there have been dark, regrettable dimensions of this American experience that have scarred the country and left wounds on segments of the population that the Nation has yet to address.

But we are a resilient nation. For more than 200 years to today, the culture of discovery, taking great risks for great gains, and bouncing back from tremendous lows have been deeply ingrained in the American DNA. These characteristics have delivered prosperity, increasing standards of living, and an improving quality of life for most Americans. More than ever before, the United States needs to express this DNA, as it is likely to be the determining factor in shaping and ensuring our future global leadership and prosperity.

# The Warning Lights are Flashing

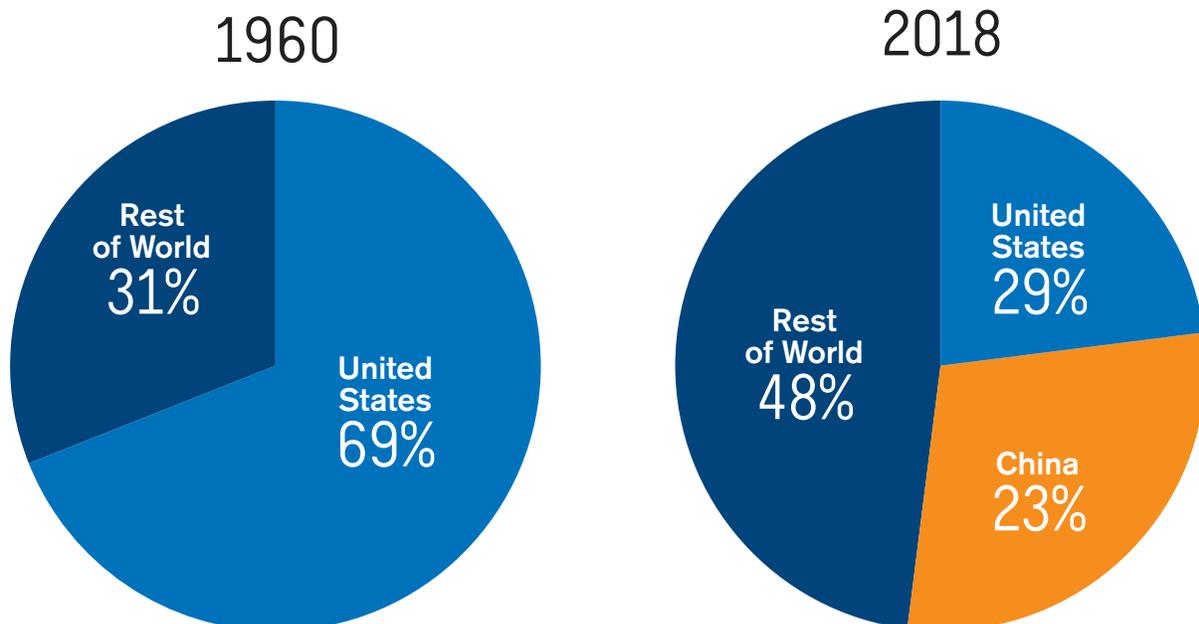
**The “check the innovation engine light” is on. The U.S. global position in technology and its foundations are eroding.** In 1960, the United States dominated research and development (R&D), accounting for a 69 percent share of global R&D investment. The United States could drive developments in technology—and the ensuing innovations—globally by virtue of the size of its investment. Today, we have evolved into a multipolar science and technology world, and all countries have access to new knowledge and emerging technologies. As other nations have increased their R&D investments, the U.S. global share has dropped to 29 percent in 2018,

diminishing the U.S. dominance and leverage over the direction of technology advancement, and China has risen to account for nearly a quarter of global R&D spending.

A nation's R&D intensity, expressed as R&D expenditures as a percentage of GDP, provides another gauge of national R&D performance. In this measure, the U.S. position globally has lagged in recent years, while other countries have expanded their R&D activities. U.S. R&D investment as a percent of GDP ranks 10th in the world, behind major U.S. competitors such as Taiwan, Japan, Germany, and South Korea which ranks at the top in this metric.

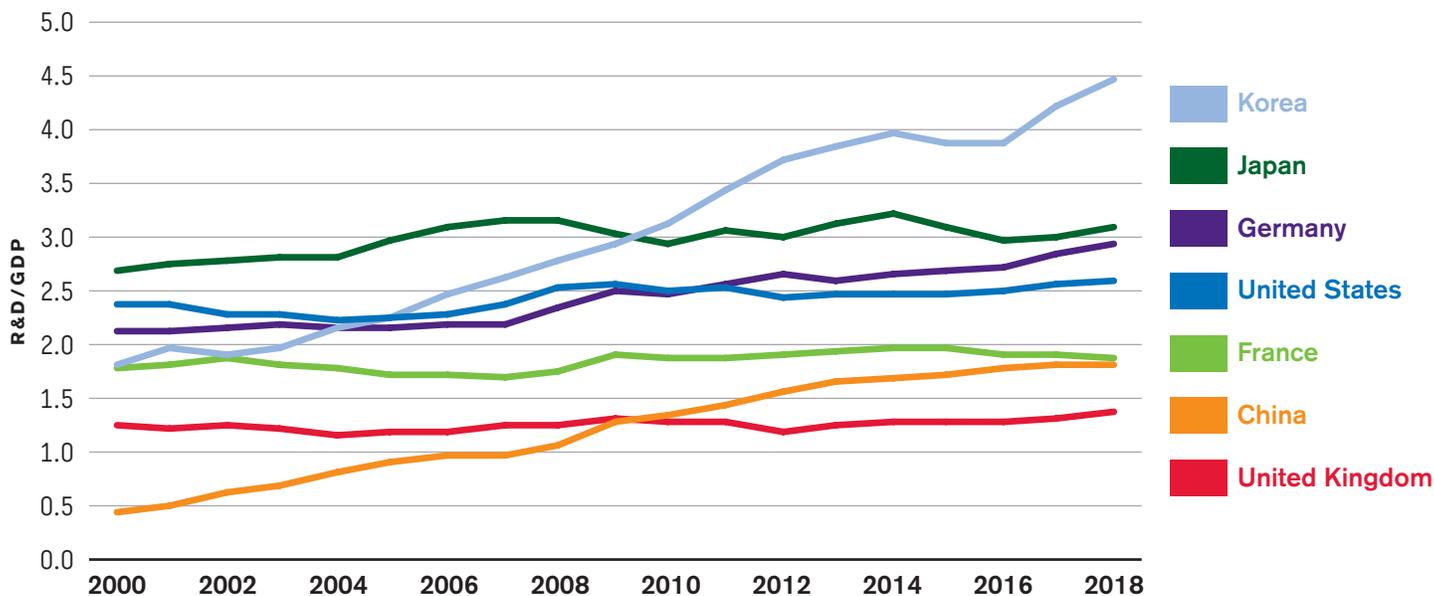
## Figure 1. U.S. Share of Global R&D Expenditures

Source: U.S. Department of Commerce, Office of Technology Policy, *The Global Context for U.S. Technology Policy*, Summer 1997; OECD Main Science and Technology Indicators.



**Figure 2. Gross Expenditure on R&D as Percent of GDP**

Source: OECD Main Science and Technology Indicators



With a 32.1 percent global share, the United States remains the world leader in high R&D intensive industries (aircraft; computer, electronic, and optical products; pharmaceuticals; scientific R&D services; and software publishing). However, China's global share has grown rapidly, from 5.6 percent in 2002 to 20.6 percent in 2018, surpassing Japan and the EU. China has made the largest gain in the computer, electronic, and optical products industry, in which its output has grown nine-fold since 2002, capturing world leadership in production in 2013, while also making major inroads in the world's clean energy technology infrastructure—from PV solar manufacturing to lithium-ion batteries.<sup>6</sup>

At the same time, we see a rise in Chinese-driven debt financing, as well as an uptick in activity from national infrastructure banks and sovereign wealth funds in nations as diverse as Australia, Brazil, and the United Arab Emirates, America's lead in its vaunted innovation financing toolkit—venture capital—is shrinking. In 1992, U.S. investors led 97 percent of that year's \$2 billion in venture finance and

accounted for about three-quarters just a decade ago. However, in 2017, U.S. investors led 44 percent of a record \$154 billion in venture finance, with Asian investors (with China leading) accounting for 40 percent.<sup>7</sup> Global venture investment has increased dramatically, from \$26 billion in 2004 to \$308 billion in 2018 and \$257 billion in 2019. However, while the absolute level of venture capital coming to the United States has increased substantially, the global share going to U.S. start-ups has dropped sharply from 84 percent in 2004, to about half in 2019.<sup>8</sup>

While traditional U.S. competitors—such as the EU, Japan, and the U.K.—continue to be strong R&D performers working at the leading edge of technology, many smaller, often overlooked regions and nations have distinctive strategies to build global innovation competency and competitiveness. Many emerging economies seek to follow the path of the world's innovators, transform to knowledge-based economies, and drive their economic growth with technology and innovation. They are establishing government organizations and ministries focused

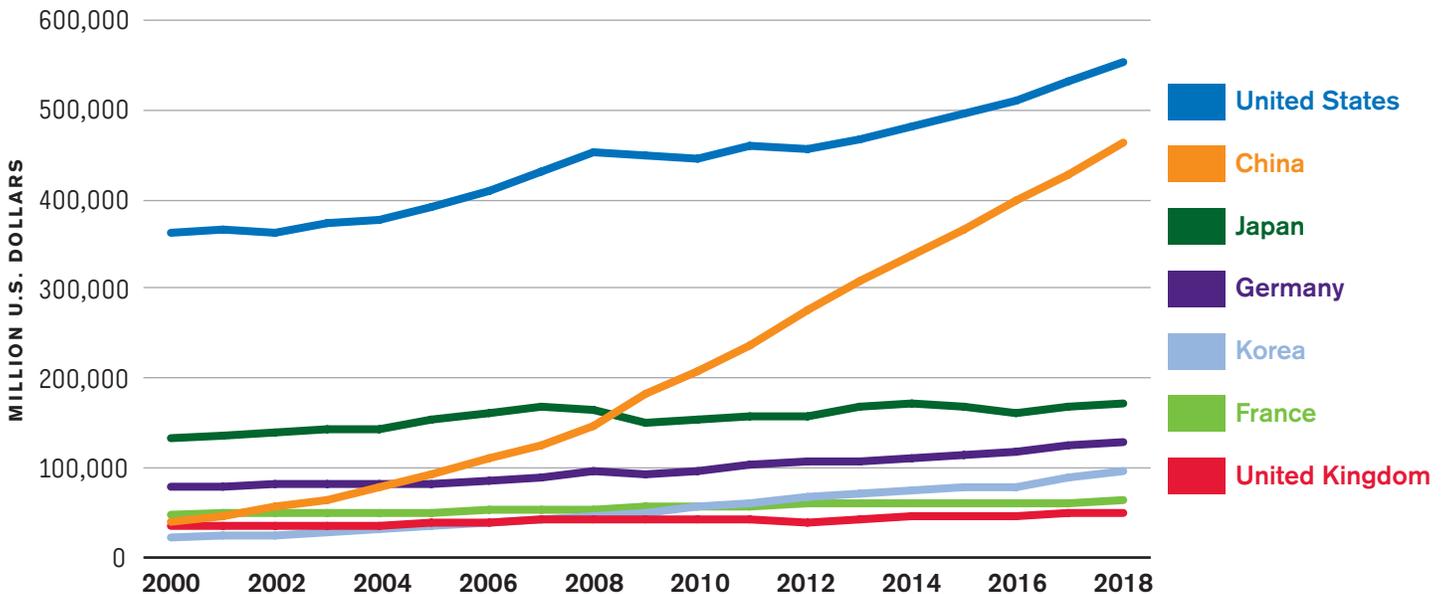
6 The State of U.S. Science and Engineering 2020, National Science Foundation; 2015 Research Highlights, Clean Energy Manufacturing Analysis Center, U.S. Department of Energy National Renewable Energy Laboratory, 2015.

7 Silicon Valley Powered American Tech Dominance—Now it has a Challenger, Wall Street Journal, April 12, 2018.

8 Global VC Investment, National Venture Capital Association.

**Figure 3. Gross Domestic Expenditure on R&D, 2000–2018**

Source: OECD Main Science and Technology Indicators



on technology and innovation, adopting innovation-based growth strategies, boosting government R&D investments, and developing research parks and regional centers of innovation. Some of these economies are also working to increase their production of scientists and engineers. These actions are raising technology development capabilities and innovation capacity around the world. These emerging innovators alone may not pose a significant threat to the United States but, collectively, can present a challenge to the U.S. economy and national security.

Most notable for its rapidly strengthening position, China poses an especially formidable and growing strategic competitive challenge in the science and technology arena. China's investment in R&D has more than doubled since 2010, reaching \$468 billion in 2018, second only to the U.S. investment of \$582 billion.<sup>9</sup> While the United States still leads in basic and applied research investment, China has surpassed the United States in spending on experimental development by \$70 billion.<sup>10</sup>

China's output of science and engineering publications has risen nearly tenfold since 2000, overtaking the United States. China has a 21 percent world share, while the United States has a 17 percent share.<sup>11</sup> China has also overtaken the United States in international patenting. For the first time since the Patent Cooperation Treaty System went into effect in 1978, patent applicants residing in China out-filed applicants in the United States. With 58,990 applications in 2019, China has a 22.1 percent share of international patent applications, surpassing the U.S. 57,840 applications and 21.8 percent share.<sup>12</sup>

Key U.S. science and technology infrastructure is eroding. America's national laboratory system is considered a globally distinctive competitive asset. But, across the system, core scientific and technological capabilities are potentially at risk due to deficient and degrading infrastructure, as well as burdensome and outmoded regulations and mission constraints that impede the laboratories' abilities to contribute to the advances in technologies that will underpin future economic growth and national security. Space

9 OECD Main Science and Technology Indicators.

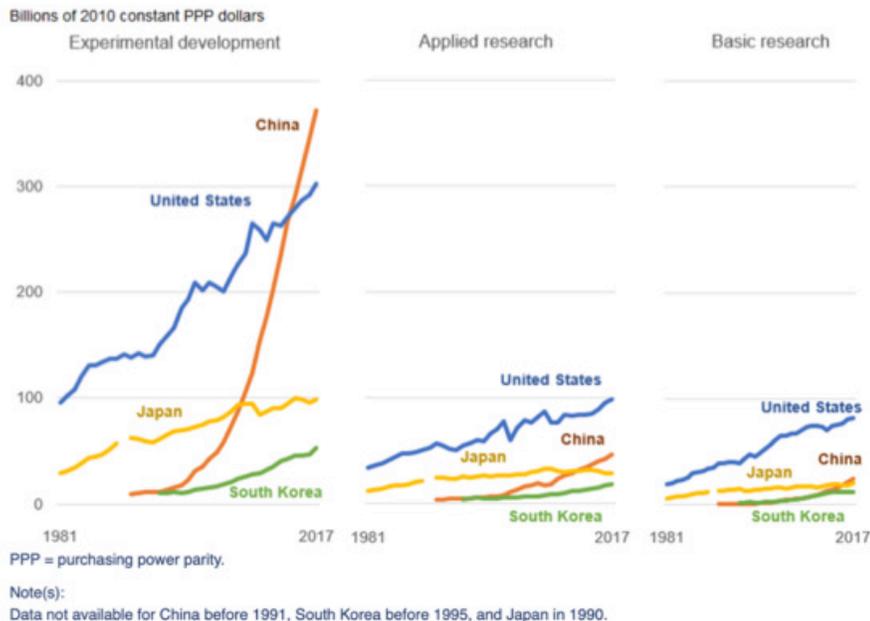
10 The United States Invests More in Applied and Basic Research than Any Other Country but Invests Less in Experimental Development than China, National Center for Science and Engineering Statistics, National Science Foundation, December 2019.

11 The State of U.S. Science and Engineering 2020, National Science Foundation.

12 Patent Cooperation Treaty Yearly Review 2020, World Intellectual Property Organization, 2020.

## Figure 4. China Leads the World in Experimental Development Spending

Source: OECD Research and Development Statistics, Gross domestic expenditure on R&D by sector of performance and source of funds ([https://stats.oecd.org/Index.aspx?DataSetCode=GERD\\_TORD](https://stats.oecd.org/Index.aspx?DataSetCode=GERD_TORD), accessed 23 August 2019) and NCSSES, National Patterns of R&D Resources (annual series).



in many facilities within the system is old, outdated, even obsolete, with maintenance and repair hamstrung by chronic underfunding, and maintenance backlogs in the hundreds of millions of dollars.

For example, the U.S. Department of Energy (DOE) has a vast portfolio of world-leading scientific infrastructure and production assets developed over the past 75 years, including 17 national laboratories. With a replacement plant value of more than \$130 billion, the land, facilities and other assets that comprise this infrastructure represent some of America's premier assets for science, technology, innovation, and security. This infrastructure is degrading with only about half of DOE-owned buildings and trailers rated as adequate to meet the mission, and levels of deferred maintenance continue to rise, putting core capabilities in areas such as bioenergy research, materials and chemical science and technology, mechanical and thermal engineering, climate and atmospheric science, and biological systems science at risk.<sup>13</sup> Moreover, the national laboratory systems'

science and engineering workforce is aging, and the competition for top STEM talent is fierce.

In other important facilities, at the National Institute of Standards and Technology, more than half of the facilities on its two main campuses are in poor to critical condition. Older NIST labs are unable to support controlled environments required for advanced research.<sup>14</sup> At NASA, about 82 percent of infrastructure and facilities are beyond their constructed design life.<sup>15</sup>

## China's Rise and Ambitions Have Fundamentally Changed the Technological, National Security, Economic, and Geopolitical Landscape

China seeks to supplant the United States as the world's technological, economic, military, and geopolitical leader. The United States has faced formidable

13 Annual Infrastructure Executive Committee Report to the Laboratory Operations Board, U.S. Department of Energy, March 27, 2018.

14 NIST Facilities Overview, Office of Facilities and Property Management Presentation before the NIST Visiting Committee on Advanced Technology, February 11, 2020.

15 FY 2021 Budget Estimates, National Aeronautics and Space Administration.

strategic competitors in the past. During the Cold War, the Soviet Union sought military supremacy, but could not secure global economic and market leadership. During the 1980s, in the competition between the United States and “Japan, Inc.”—in autos, machine tools, steel, and consumer electronics—Japan sought commercial market dominance, but not military superiority. China seeks both.

To achieve its superpower goals, China seeks to build a science and technology capability rivaling the size and breadth of the U.S. capability. It seeks to create the mechanisms to innovate—commercializing its growing achievements in science and technology—and sees business enterprises as playing the prime role. The government’s role involves overall planning, and promoting the linking of capital, technology, and markets. China recognizes the gap between basic research and technology commercialization, and states that government will work to resolve this connection problem.<sup>16</sup>

## China’s Strategic Technology Plans

With the objective of dominating the next generation of innovation, China is pursuing aggressive plans for every strategic critical underlying technology, backed by commitments for hundreds of billions of dollars in investment.

For example, the *Made in China 2025* initiative, announced in 2015, seeks to transform China from a manufacturing giant into a global science and technology power by 2049 (the 100th anniversary of the People’s Republic of China), while it set a target to become one of the most innovative countries by 2020 and a leading innovator by 2030.<sup>17</sup> *Made in China* targets advanced IT, advanced machine tools,

robotics, aerospace technology, maritime equipment, new energy vehicles, biomedicine and advanced medical equipment.<sup>18</sup>

China is targeting development of the entire semiconductor ecosystem, including spending of more than \$150 billion over 10 years for investments and acquisitions.<sup>19</sup> In August 2020, the Chinese government updated its semiconductor policy to emphasize foreign academic and industry collaboration (including domestic and overseas R&D centers), expanding China’s role in developing international rules for protection of intellectual property, advancing Chinese standards, use of antitrust authorities, and priority financing vehicles.<sup>20</sup> China’s semiconductor policies include a strong government role in directing and financing Chinese businesses to obtain foreign intellectual property related to semiconductors. The Chinese government uses production targets; subsidies; tax preferences; trade and investment barriers (including pressure to engage in joint ventures); and discriminatory antitrust, IP, procurement, and standards practices. The policies seek to develop China into a semiconductor production hub that would exert pressure on foreign companies to localize production, share technology, and partner with the Chinese government and affiliated entities.<sup>21</sup>

In 2010, China made a major move in life sciences research when its company BGI purchased 128 of the world’s fastest gene sequencers, half the global capacity for gene sequencing at that time. Today, China accounts for 30 percent of the world’s sequencing capacity.<sup>22</sup> In a recently translated speech, Chinese President Xi Jinping emphasized that China must place greater emphasis on basic research in heredity, genetics, virology and related

16 Speech on Certain Major Issues for Our National Medium- to Long-term Economic and Social Development Strategy, President Xi Jinping in April 2020 (translated), Center for Security and Emerging Technology, and Etcetera Language Group, November 10, 2020.

17 China’s Technology Transfer Strategy: How Chinese Investments in Emerging Technology Enable A Strategic Competitor to Access the Crown Jewels of U.S. Innovation, Defense Innovation Unit Experimental, January 2018.

18 *Made in China 2025: Global Ambitions Built on Local Protections*, U.S. Chamber of Commerce, 2017.

19 *Made in China 2025: Global Ambitions Built on Local Protections*, U.S. Chamber of Commerce, 2017.

20 China State Council, “Notice on Issuing Several Policies to Promote the High-Quality Development of the Integrated Circuit Industry and the Software Industry in the New Period,” August 4, 2020.

21 Semiconductors: U.S. Industry, Global Competition, and Federal Policy, Congressional Research Service, October 26, 2020.

22 2018 Global R&D Funding Forecast, R&D Magazine, Winter 2018.

## Figure 5. China's Strategic Goals and Tools

Source: Federal Bureau of Investigation, <https://www.fbi.gov/file-repository/china-risk-to-corporate-america-2019.pdf/view>.



fields; accelerate R&D and technological innovation of related drugs and vaccines; and elevate the importance of applying information and data technologies to these fields.<sup>23</sup> It plans to support the establishment of a cellular genetics and genetic breeding technology R&D center, a synthetic biotechnology innovation center, and a biotech and pharmaceutical innovation Center to accelerate the pace of innovation and development for the biotech industry.

And, in September 2020, the Chinese Communist Party Central Committee and State Council released *Guiding Opinions on Expanding Investment in Strategic Emerging Industries and Cultivating Strengthened New Growth Points and Growth Poles*.<sup>24</sup> The guidance is focused on economic and social development, including accelerated promotion of strategic emerging industries and industrial clusters. However, taken as a whole, it conveys a 20 point high-level strategic plan for the technological

23 Speech on Certain Major Issues for Our National Medium- to Long-term Economic and Social Development Strategy, President Xi Jinping in April 2020 (translated), Center for Security and Emerging Technology, and Etcetera Language Group, November 10, 2020.

24 Translation jointly produced by DigiChina, Stanford University Cyber Policy Center, in partnership with New America and the Center for Security and Emerging Technology at Georgetown University.

transformation of China's economy and society, and assigns responsibility for its implementation to key governmental ministries and organizations. It calls for building out the ecosystems, supportive financing mechanisms, and investment in technology development, demonstration, and deployment across Chinese industry and society of every strategic critical technology. This includes technologies and industries pioneered and dominated by the United States, ranging from biotechnology to the digital creative industry.<sup>25</sup>

This guidance builds on China's previously released strategic plans. A new *14th Five-Year Plan*, coming from the National People's Congress in early 2021, is expected to **identify innovation as a core national strategy** for China's economic growth.<sup>26</sup>

## China's Accelerating Efforts to Acquire and Absorb Foreign Technology

China is deploying a multi-pronged strategy to acquire technologies and intellectual property from other countries by both licit and illicit means. This

<sup>25</sup> **Areas of technology investment:** 5G, AI, the Industrial Internet, Internet of Things, Internet of Vehicles, big data, and cloud computing; biotechnology; materials for microelectronics, high performance fibers, nanomaterials, rare earth materials, optoelectronics, energy, and bi-medicine; new energy technologies.

**Areas of demonstration:** smart manufacturing and smart construction; green travel, green shopping, green restaurants, and green e-commerce

**Areas of deployment:** smart broadcasting, smart water conservation, smart ports, smart logistics, smart municipal administration, smart communities, smart housekeeping, smart tourism, online education and medical care; agricultural and rural big data centers; intelligent and alternative energy vehicles, construction of electric vehicle charging infrastructure, Internet of Vehicles, and big data centers for autonomous driving operations; green construction and distribution; electronic gaming centers, highly immersive product experience exhibition centers, virtual reality tourism, augmented reality marketing, digital museums, creative design, and smart sports

**Areas of industrial and innovation ecosystem development:** high-end equipment industry and digital creative industry; industry innovation centers, engineering research centers, industry metrics and testing centers, quality inspection centers, company technology centers, standards innovation bases, technology innovation centers, manufacturing industry innovation centers, and industry intellectual property operation centers.

<sup>26</sup> China's 13th Five-Year Plan of 2016-2020 Internet Plus focuses on raising the country into a leading position and deployer in big data, AI, smart hardware, displays, advanced sensors, wearable devices and mobile communications; China's Fifth Plenum: What You Need to Know, *The Diplomat*, October 29, 2020; China Sets "Pragmatic" Targets Through 2025, *Global Times*, October 29, 2020.

## China's Plans: By the Numbers

10 Strategic Emerging Industrial Bases  
 100 Strategic Emerging Industry Clusters  
 1,000 Strategic Emerging Industry Ecosystems

includes building research centers in U.S. innovation hubs, forming partnerships with U.S. research universities, forced joint ventures for market access, sending students to the United States for academic studies, cyber theft, and industrial espionage.

The U.S. Trade Representative reports that China has engaged in a range of unfair and harmful conduct, including investment and other regulatory requirements that require or pressure technology transfer, and direction or facilitation of the acquisition of foreign companies and assets by domestic firms to obtain cutting-edge technologies.<sup>27</sup> China's National Intelligence Law requires private companies to cooperate with its national intelligence agencies, raising concerns that this law could require companies to turn over sensitive data, trade secrets, or intellectual property to the Chinese government or military.

China remains the world's principal intellectual property (IP) infringer, and most active and persistent perpetrator of economic espionage. The U.S. Trade Representative (USTR) reports that China has engaged in supporting unauthorized intrusions and theft from computer networks of U.S. companies to obtain unauthorized access to intellectual property. According to the USTR, the U.S. government has evidence that the Chinese government provides

<sup>27</sup> Findings of the Investigation into China's Acts, Policies, and Practices Related to Technology Transfer, Intellectual Property, and Innovation Under Section 301 of the Trade Act of 1974, Office of the United States Trade Representative, March 22, 2018.

competitive intelligence through cyber intrusions to Chinese state-owned enterprises through a process that includes a formal request and feedback loop, as well as a mechanism for information exchange via a classified communication system.<sup>28</sup>

As China is committed to industrial policies that include maximizing the acquisition of foreign technologies, particularly in high-tech sectors, these policies could drive even greater IP theft, and pressure to transfer technology. The pilfering of intellectual property can save countries significant time, money, and resources while achieving generational advances in technology.

China is not the only country where IP protection and enforcement are inadequate. For example, long standing IP challenges facing U.S. businesses in India include those which make it difficult for innovators to receive and maintain patents in India, particularly for pharmaceuticals. Numerous other countries present a variety of IP protection and enforcement problems such as patentability criteria, inadequate protection for trade secrets, and lack of IP enforcement.

China is sending its students to learn at the world's best universities, with a laser focus on studying leading-edge areas of science and technology and

### Strategy of Introducing, Digesting, Absorbing, and Re-innovating Foreign Intellectual Property and Technology

Source: Office of the U.S. Trade Representative

China's National Medium- and Long-Term Science and Technology Development Plan Outline (2006–2020) (MLP) is the seminal document articulating China's long-term technology development strategy. It identifies 11 key sectors, and 68 priority areas within these sectors, for technology development, and designates eight fields of "frontier technology," within which 27 "breakthrough technologies" will be pursued. Section 8(2) of the MLP calls for "enhancing the absorption, digestion, and re-innovation of introduced technology." Subsequent policies articulate the concept of Introducing, Digesting, Absorbing, and Re-innovating foreign intellectual property and technology (IDAR):

- **Introduce:** Chinese companies should target and acquire foreign technology. Methods of "introducing" foreign technology that are referenced include: technology transfer agreements, inbound investment, technology imports, establishing foreign R&D centers, outbound investment, and the collection of market intelligence by state entities.

28 Findings of the Investigation into China's Acts, Policies, and Practices Related to Technology Transfer, Intellectual Property, and Innovation Under Section 301 of the Trade Act of 1974, Office of the United States Trade Representative, March 22, 2018.

- **Digest:** Following the acquisition of foreign technology, the Chinese government should collaborate with China's domestic industry to collect, analyze, and disseminate the information and technology that has been acquired.
- **Absorb:** The Chinese government and China's domestic industry should collaborate to develop products using the technology that has been acquired. The Chinese government should provide financial assistance to develop products using technology obtained through IDAR. To absorb foreign technologies, authorities have established engineering research centers, enterprise-based technology centers, state laboratories, national technology transfer centers, and high-technology service centers.
- **Re-innovate:** Chinese companies should "re-innovate" and improve upon the foreign technology.

Since first articulated in 2006, China has continued to emphasize the IDAR approach in broad-ranging five-year plans and technology plans issued by China's State Council, central government ministries, provincial and municipal governments, and China's Communist Party. The IDAR approach also has been incorporated into numerous economic development plans for specific sectors, such as integrated circuits.

bringing what they learn back to China. After returning to China, these "sea turtles" are building China's high-technology industries and companies.

There is growing concern about China's presence on U.S. college campuses. In 2018-19, there were more than 369,500 Chinese foreign nationals studying at U.S. colleges and universities, one-third of all foreign students.<sup>29</sup> Many of these students are in U.S. science and engineering graduate programs. Most do not have visas to stay in the United States and will return to China. Chinese companies seek research partnerships with U.S. universities, and are setting up research centers in the United States to access U.S. talent and technology. State-backed Chinese enterprises increasingly finance joint research programs and the construction of new research facilities on U.S. campuses.

## China's Talent Recruitment

China's talent recruitment programs are also raising red flags. These programs target U.S.-based and other researchers around the world who focus on or have access to cutting-edge research and technology. In recent years, federal agencies have discovered talent recruitment plan members who downloaded sensitive electronic research files before leaving to return to China, submitted false information when applying for federal grant funds, and willfully failed to disclose receiving money from the

Chinese government on federal grant applications. In some cases, talent program members received both U.S. grants and Chinese grants for similar research, established “shadow labs” in China to conduct parallel research, and stole intellectual property. Several high-profile arrests have been made.

For example, the National Institutes of Health (NIH) has identified failure by some researchers at NIH-funded institutions to disclose receiving resources from other organizations, including foreign governments; diversion of intellectual property in grant applications or produced by NIH-supported biomedical research to other countries; and, in some instances, sharing of confidential information by peer reviewers with others including, in some instances, with foreign entities, or otherwise attempting to influence funding decisions.<sup>30</sup>

An investigation by the United States Senate Homeland Security Committee found members of China’s Thousand Talents Plan worked on sensitive research at U.S. Department of Energy national laboratories and maintained security clearances. One member used intellectual property created during work in a national lab and filed for a U.S. patent under the name of a Chinese company, stealing the U.S. government-funded research and claiming it for the Chinese

company. Another member downloaded more than 30,000 files from a national laboratory without authorization right before this individual returned to China.

### **China’s Growing Role in Geopolitics**

China seeks to shape large swaths of the 21st century global economic and trading system. It has been using its growing role in multilateral institutions and in the global trading system to advance its mercantilist dominance, including deploying a debt-financed development infrastructure model in other countries, as the United States’ international engagement has atrophied. For example, China’s Belt and Road Initiative is staggering in scope, a new Silk Road of railways, energy pipelines, highways, shipping lanes, and special economic zones, fueled by \$1 trillion in Chinese investment. The initiative would touch more than 4 billion people, 65 countries, and \$23 trillion in GDP.<sup>31</sup>

Through Belt and Road, China is massively financing, constructing, gaining ownership, and operating critical infrastructure in the Eurasian Region, including a new “Digital Silk Road.” It seeks to transform global infrastructure in its model, and shape digital infrastructure and connectivity. This has the potential not only to promote Chinese high technology, but also its control over commercial product, service,

30 Michael S. Lauer, M.D., Deputy Director for Extramural Research, National Institutes of Health, Testimony before the Senate Homeland Security and Government Affairs Permanent Subcommittee on Investigations Hearing on Securing the Research Enterprise from China’s Talent Recruitment Plans, November 19, 2019.

31 Center for Strategic and International Studies, China Power Project.

and data flows. China's 17+1 is a new foreign policy framework for the region's countries, which includes collaboration on advanced technologies such as the digital economy, artificial intelligence, financial technology, and the life sciences. 17+1 could create a regional context that undermines the EU's unity, given that 12 of the 17 are members of the EU.

Belt and Road and 17+1 serve China's economic and geopolitical goals and could align a large part of the world economy toward China, and position China to shape the rules and norms of economic activity in the region. However, some of the 17+1 countries are rethinking close partnership with China, due to stalled infrastructure projects, and push-back from the United States.<sup>32</sup>

32 China's 17+1 Initiative Stalls Amid Security Concerns and Broken Promises, *The Strategist*, Australian Strategy Policy Institute, October 20, 2020.

10x

## A NEW INNOVATION AGE CALLS FOR A NEW INNOVATION GAME

# 10x: Leadership and National Strategies for Innovation

Technology and innovation—the combination of imagination, insight, ingenuity, invention, and impact in society—are the main drivers of U.S. economic growth and productivity, the main shapers of the future, and principal determinants of economic opportunities and national security for Americans. With such impact for the Nation, U.S. capacity, capability, and performance in leveraging new technology for economic gain and for innovating should be at the top of the economic and national security agenda, and of major concern to U.S. public and private sector leaders.

Today, the United States faces new and hard competitive realities at home—for example, limited engagement of too many Americans in the Nation’s world-class innovation economy—and from abroad. At the same time, as multiple technology revolutions unfold, the United States is presented with unprecedented opportunities for innovations that can drive new business formation, inclusive economic growth, high-wage job creation for more Americans, and wealth generation.

However, our fundamental ability to answer these challenges, and leverage new game-changing technologies for inclusive economic impact are eroding. There are deficiencies in the U.S. innovation ecosystem, barriers in developing and scaling new technologies, too many Americans locked out of the innovation sector due to inadequate opportunity, education and skills, and insufficient U.S. leadership in the international developments that are setting the stage and rules for the next global economy. If the United

“With a \$20 trillion economy, a diverse population of over 330 million people, the United States is an incredible incubator of ideas...

“...What we need now is a ‘modernization model’ - we must be unbelievably creative in re-inventing America.”

**Dr. Michael Crow**  
President  
Arizona State University

States does not mount a strong response to these new competitive threats, our economy, standard of living, national security, and geopolitical position will all be at increasing risk.

Meeting the new strategic competitive challenge, addressing the deficiencies in our innovation ecosystem, and fully leveraging the technological possibilities before us will require a “whole-of-nation” approach that engages our leaders in the federal government, U.S. governors and other state and local officials who have charge over a growing part of the U.S. innovation ecosystem, labor leaders, the heads of our universities, and the top executives of U.S. companies.

## Challenges, Threats, and Rising Opportunities Demand a New, Dedicated Federal Innovation and Competitiveness Leadership Structure

There are many factors that affect a country's ability to innovate and compete. These include: investment in research and development; the availability of capital for innovation at critical stages; the access to and provision of education that develops a growing base of qualified, diverse, innovation-prepared talent; the ecosystem for entrepreneurship; and the general business environment including taxes, fiscal policy, trade policies, and business regulation. In addition, how these factors affect innovators and business can vary depending on company size, whether in an infant or mature industry, capital or labor intensity of the industry, services or manufacturing, and the life-cycle of technologies and products in the industry. To address these diverse factors, some U.S. competitors have established high-level ministries, government departments, or other organizations devoted to stimulating technology and innovation and to guide national strategic plans.

In the past, the United States has had federal entities that addressed the scope of issues and factors that affect innovation and competitiveness, and sought to better integrate the federal leadership role in program coordination, analysis, and policy development. Also, Congress had an Office of Technology Assessment that performed critical studies to advise Congress on the role of technology in the economy and society. However, these entities did not survive changes of Presidential Administrations, reached sun sets as provided for in their authorizations, or were eliminated as budgetary saving measures.

### **As a result, the United States does not have in the federal government a single leadership structure for U.S. innovation and competitiveness, and related capacity and capabilities.**

Instead, policy formulation is fragmented as responsibility for addressing the factors that affect innovation

and competitiveness cuts across many stove-piped missions of federal departments and agencies, multiple bodies within the Executive Office of the President, competing Presidential Cabinet-level councils, and multiple Congressional committees.

The closest integrative bodies are the National Economic and Domestic Policy Councils. The White House Office of Science and Technology Policy's scope of work revolves largely around federal science and technology policy, and federal R&D investment and programming. However, many critical policies having an impact on the Nation's innovation capacity and outcomes are within the purview of other White House bodies, such as the Council of Economic Advisors, the Office of Management and Budget, the National Security Council, etc.

In contrast, for example, the President's Commission on Industrial Competitiveness of the 1980s—the precursor to the Council on Competitiveness—addressed a range of issues in addition to research and technological innovation, including global trade policy, tax policy, patient capital, intellectual property protection, manufacturing modernization, and regulation.

Similarly, broader in scope, the Stevenson-Wydler Technology Innovation Act of 1980 and its amendments—one of the major legislative initiatives in technology and innovation, guiding the government role for decades—outlined the scope of responsibilities vested in the leadership organization at the U.S. Department of Commerce.<sup>33</sup>

Under these and follow-on authorities, the Commerce Department carried out a diverse range of activities related to competitiveness and innovation such as:

33 This scope included: determining the relationships of technology developments to U.S. economic performance; determining the impact of economic and labor conditions, industrial structure and management, and government policies on technological developments in particular industrial sectors; identifying technological needs, problems, and opportunities within and across industrial sectors; assessing the adequacy of capital and other resources being allocated to domestic industrial sectors which are likely to generate new technologies; proposing and supporting studies and policy experiments to determine the effectiveness of measures with the potential of advancing United States technological innovation; and considering government measures with the potential of advancing United States technological innovation.

- Spearheading changes in antitrust laws culminating in the National Cooperative Research Act of 1984, which reduced antitrust barriers to private sector research collaborations, opening the doors for industrial R&D consortia such as SEMATECH;
- Led the federal government's role in its partnership with the Big 3 U.S. automakers to develop a three-times fuel efficient vehicle in the Partnership for a New Generation of Vehicles;
- Through an information clearinghouse, played an early role in the transfer of Japanese manufacturing innovations, such as quality circles and just-in-time production, to U.S. industry;
- Conducting a survey on and study of the use of biotechnology in industry;<sup>34</sup>
- Identification of and Report to Congress on best practices in federal technology partnerships with industry;<sup>35</sup>
- Created the State Science and Technology Indicators, which were later transitioned to the National Science Foundation;
- Helped organize U.S. industry engagement in an international intelligent manufacturing initiative;
- Conducting roundtables coast-to-coast and the federal government's first Internet survey to develop a Report to Congress on Education and Training for the Information Technology Workforce;<sup>36</sup> and
- Staff studies of state and regional technology-based economic development programs and industry structure in Japan.

Serving a policy analysis and advisory role to the Congress, among the authorized functions and duties of the Congressional Office of Technology

Assessment (OTA)—now defunct—were identifying existing or probable impacts of technology or technological programs. In fulfilling this role, OTA produced numerous assessments of the impact of specific technologies on industry and the economy; competitiveness; education technology; workplace automation; and societal implications of technology such as the social impact of robotics, technology's impact on the labor force, as well as privacy, security, and civil liberties in an age of electronic records and surveillance.

In today's even more complex and turbulent innovation environment, domestic and global, the federal government must elevate the innovation agenda to the highest levels of decision-making. The United States needs a permanent, high-level, adequately and continually funded and staffed organization to lead national efforts to leverage new technology, and strengthen U.S. innovation and competitiveness, given their fundamental role in economic growth, job creation, and societal functioning.

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## RECOMMENDATION

The federal government should establish in the Executive Office of the President a National Competitiveness and Innovation Council (NCIC), with status similar to the National Security Council (NSC) and National Economic Council (NEC). The NCIC—which should include members from the NSC, NEC, etc.—should:

- Establish a national vision for U.S. competitiveness and innovation in the 21st century global economy
- Lead an integrated approach to policy development across the many factors that affect the U.S. ability to innovate and compete, and coordinate related federal department and agency policy development and programs in this domain
- Monitor U.S. competitiveness and innovation performance
- Research and analyze emerging technology and innovation-related issues and challenges
- Gather and analyze information on the actions of competitor nations

34 A Survey of the Use of Biotechnology in U.S. Industry, Technology Administration and Bureau of Industry and Security, U.S. Department of Commerce, November 2003.

35 Effective Partnering: A Report to Congress on Federal Technology Partnerships, Office of Technology Policy, U.S. Department of Commerce, April 1996.

36 Education and Training for the Information Technology Workforce, Report to Congress from the Secretary of Commerce, April 2003.

- Plan strategically for research and technology investment and government programming
- Catalyze needed action—including engagement with the private sector—to address challenges to U.S. competitiveness, and deficiencies in the U.S. innovation ecosystem. This includes initiating and executing large-partnerships to address strategic technology and competitiveness opportunities and threats, and advance critical technology and innovation-related goals
- Advocate for U.S. innovation and competitiveness in the domestic and international policy arena

## RECOMMENDATION

U.S. governors should establish their own State Competitiveness and Innovation Councils to work with and coordinate their innovation-related initiatives with those at the federal level.

## Establishing a New National Vision for U.S. Competitiveness and Innovation in the 21st Century Global Economy

Over the past century, game-changing innovations arose from federal investments in research and technology development that were made to achieve the science, national security, and economic missions of federal departments and agencies. For example:

- The first laboratories in our crown-jewel Department of Energy national laboratory system were established during the Manhattan Project to develop an atom bomb. For 50 years, the Departments of Defense and Energy have played a pivotal role in advancing high performance computing to meet their missions—for example, for cryptanalysis, signals processing, and nuclear weapons testing and verification—providing the early funding and market to build the U.S. supercomputing industry, which dominates global markets today as a deep public-private partnership.
- Driven by their missions in defense and science, DARPA and the National Science Foundation invested in the development of packet-switched networks—a critical development that led to today’s Internet. Early investments by the National Institute of Standards and Technology to develop atomic clocks, and investments by the Department of Defense to develop a way to locate submarines were responsible for development of the Global Positioning System—vital for the operation of satellites, and deployed in cell phones and vehicle navigation systems worldwide. DARPA also provided the key early investments in artificial intelligence.
- The Department of Energy, in collaboration with industry, advanced the horizontal drilling, hydraulic fracturing, and micro-seismic monitoring technologies that have produced a game-changing U.S. oil and natural gas boom.
- A recent study showed that National Institutes of Health (NIH) funding contributed to the published research associated with every one of the 210 new drugs approved by the Food and Drug Administration from 2010–2016.<sup>37</sup> Investments in science and in the Human Genome Project by NIH, the U.S. Department of Energy, and National Science Foundation laid the foundation for the U.S. biotechnology industry and its world leadership.

For 75 years, the foundational vision for the federal government’s role in science and technology has been rooted in the findings and recommendations of Vannevar Bush’s seminal 1945 report to the President, *Science: The Endless Frontier*. The report found that progress in fighting disease, the creation of new products and industries, job creation, and national security depend on a flow of new scientific knowledge that can only be obtained through basic research. He cited the need to compensate for diminishing financial support for basic medical research at U.S. medical schools and universities.

<sup>37</sup> Contribution of NIH Funding to New Drug Approvals 2010–2016, Cleary, et. al., Proceedings of the National Academy of Sciences, March 6, 2018.

He also pointed to the scientific techniques such as radar that gave the allies a decisive winning edge in World War II, and the need for government funds for military research in peacetime to ensure U.S. national security.

The report identified the post-war need for creating jobs by making new and cheaper products in vigorous enterprises, founded on new principles and concepts resulting from basic research or “scientific capital,” for which the United States could no longer depend upon Europe as a major source. To generate that scientific capital, the report calls for an adequate supply of men and women trained in science for that purpose, and strengthening the centers of basic research at colleges, universities, and research institutes.

The report concludes that the federal government should accept new responsibilities for promoting the flow of new scientific knowledge and the development of scientific talent in our youth. Basic research should be strengthened by use of public funds, and that government should provide for a reasonable number of undergraduate scholarships and graduate fellowships. Seventy-five years later, and as envisioned by Vannevar Bush, the federal government provides \$33 billion for R&D at U.S. universities and colleges, research on health and defense account for about three-quarters of the federal R&D budget,<sup>38</sup> and the federal government provides more than \$1.5 billion annually for science and engineering fellowships, traineeships, and training grants at colleges and universities.<sup>39</sup>

## A New Game

When Vannevar Bush set forth his vision for the government role in science and technology, the United States had emerged from World War II as the only superpower, markets were largely domestic, the United States faced little economic or industrial com-

petition, and there was no scientific or technological race until the Soviet Union launched the world's first artificial satellite in 1957.

Over the next six decades, the United States and all nations underwent radical and accelerating transformation with the emergence of fundamentally new and disruptive conditions that are now driving future prosperity and security. Technology has globalized and all countries have access to new knowledge and emerging technologies. Investment capital moves globally with the click of a computer mouse. Nations around the world seek to build their economies on technology and innovation, and leverage those to compete in global markets. The United States faces an ever more crowded competitive playing field, and competitive pressures drive accelerating technology development and product life-cycles. A rising and strengthening strategic competitor in China seeks to overthrow the United States as the world's technological, economic, military, and geopolitical leader.

The landscape for applying emerging technologies to advance public welfare has expanded significantly, as the world grapples with grand challenges in areas such as ensuring adequate food and clean water, cleaner energy, health, and climate.

The private sector's primary role in advancing technologies needed in the economy, and for military and homeland defense is erasing the boundary between national security and economic security. For example, U.S. military capabilities have become digitalized, and rely on the strength of commercial industry and its advances in semiconductor technology. Similarly, the military is increasingly implementing advanced materials, artificial intelligence (AI), and autonomous systems such as robotic equipment and drones in its operations—and the commercial sector is driving all of these advances. The U.S. energy sector and other segments of U.S. critical infrastructure have become digitalized and also rely on commercial technology advancements. The commercial competitive strength of U.S. industry is now fundamental to U.S. security.

38 Federal R&D Funding, by Budget Function: Fiscal Years FY 18-20, National Science Foundation, December 4, 2019.

39 Federal Obligations for Science and Engineering Fellowships, Traineeships, and Training Grants to Universities and Colleges by State, Outlying Area, and Agency: FY 2018, National Science Foundation.

## Evolution of the Federal Role in Advancing New Technology

Beyond its traditional engagement with the defense industrial base to meet its military needs, over the years since the release of *Science: The Endless Frontier*, the federal government's role in technology development has evolved. This accelerated particularly in the 1980s as the United States faced a strong competitive challenge from Japan. And, as the government's role has evolved, it has increasingly engaged the private sector in new collaborative models and partnerships.

- To leverage federally-funded R&D for commercial gain, Congress passed the Bayh-Dole Act of 1980, setting forth a uniform policy permitting universities and small businesses to retain ownership and market the inventions they create using federal research funds, and requiring non-profits to share royalties from licenses with the inventor—providing incentives to businesses, and universities (and their researchers) to move their inventions to the marketplace. Subsequent legislation extended the licensing and royalty provisions of Bayh-Dole to federal researchers and federal contractors, and cleared the way for collaboration between the private sector and federal laboratories under cooperative research and development agreements.
- In 1987, President Reagan issued an eleven point superconductivity initiative, proposing to relax antitrust rules for private sector joint production ventures, provide “quick start” grants for good ideas on processing superconducting materials into useful forms, establish four centers for research on superconducting materials, and spend \$150 million in an R&D effort by the Department of Defense.

During the 1980s, the U.S. semiconductor industry lost to Japan a significant portion of its market share for semiconductors, a threat to both U.S. military and economic security. In response, several semiconductor and computer companies formed SEMATECH, and Congress authorized the Department of Defense to make grants to SEMATECH to defray R&D costs, anticipating providing a cost-shared \$100 million annually for five years. The initial goal was to demonstrate the capability to manufacture state-of-the-art semiconductors using only U.S. manufacturing equipment.

As the U.S. industrial base faced increasing challenges from global competition, recognition grew in the public and private sectors that the United States should not only be a leader in advanced technologies, but also a leader in manufacturing those technologies. In 1988, President Reagan signed the Omnibus Trade and Competitiveness Act, establishing Regional Centers for the Transfer of Manufacturing Technology, which evolved into the Hollings Manufacturing Extension Partnership, a nationwide network of 51 centers located in all 50 states and Puerto Rico, and 375 service locations—cost shared between the federal government, and state and local governments and/or private entities—to transfer technologies and expertise to small and medium-sized manufacturers.

- During the Administration of George H.W. Bush and administered by the National Institute for Standards and Technology, the Advanced Technology Program held merit-based competitions to award grants to companies and joint ventures in partnerships with university researchers or federal labs to develop high-risk, enabling technologies with a potentially wide range of applications. A 50 percent cost share was typically required to ensure the commitment of the companies. Ultimately, the program provided funding support for more than 700 projects.

- In a high profile Clinton Administration effort launched in 1993, the federal government and the Big 3 U.S. automakers joined forces in the Partnership for a New Generation of Vehicles aimed at developing the technologies for a three-times fuel efficient vehicle. PNGV involved 13 federal departments and agencies in various aspects of the joint venture. PNGV paved the way for ongoing collaboration between the industry and government, carried out today with the Department of Energy's partnerships in U.S. DRIVE and the 21st Century Truck Partnership.

At the end of the Cold War, the Clinton Administration sought to use the “peace dividend” to ease the transition of the U.S. industrial base to technologies and products with both military and civilian uses. The Technology Reinvestment Project provided matching funds on a competitive basis to industry-led consortia to develop dual-use technologies, and other projects to deploy existing process and product technologies.

- The Obama Administration further expanded the federal government's engagement with industry. President Obama signed the American Recovery and Reinvestment Act of 2009 which appropriated significant funding to advance clean energy technologies, including large federal grants that established a government role further downstream in the innovation process. These included large grants administered by the Department of Energy to fund private company construction of production facilities and/or capacity expansion for manufacturing advanced batteries and electric drive components; and loan guarantees for clean energy and electric power transmission projects, facilities that manufacture related components, and advanced biofuel pilot or demonstration scale refineries. The 2008 Farm Bill also contributed to an extension of the government's role in promoting clean energy technology through hundreds of millions of dollars for grants and loan guarantees for

bioenergy and biofuels projects. It also provided for loan guarantees, and cost-shared grants up to a half million dollars for agricultural producers and rural small businesses to purchase renewable energy systems. The Department of Energy awarded \$60 million to the U.S. Photovoltaic Manufacturing Consortium to coordinate an industry-driven R&D initiative to advance next generation thin film PV manufacturing technologies.

Also during the Obama Administration, the National Network of Manufacturing Institutes was launched to mature and demonstrate a range of advanced manufacturing technologies. The network—now known as ManufacturingUSA—has grown to 15 institutes, with each receiving a federal cost share typically around \$70 million.

At the same time, new business models are emerging, challenging the traditional models of innovation, technology development and commercialization; cutting the linkages between production and capital; and increasing the pace of innovation by erasing boundaries between fields, sectors, and disciplines. It is now possible for someone to imagine, develop, and scale a disruptive technology independent of traditional institutions of innovation.

Given the dramatic changes that have occurred since *Science: The Endless Frontier* was written, the United States needs a bold new vision and strategy to guide its science, engineering, and innovation enterprise that reflects these new competitive realities.

Many of our competitors have developed visions, and strategies with goals and coordinative efforts among industry, government, and the academic sector. Some nations' science, technology and innovation efforts are guided by national strategic plans.

## RECOMMENDATION

A new White House National Council on Innovation and Competitiveness should initiate a national process—through an advisory body, as well as hearings, town halls, workshops, and a public request for information across the Nation—to gather ideas from the private sector, academia, state and local governments, and other stakeholders, and develop a vision to guide the Nation and the federal government's role in science, technology, and innovation. The vision should address, at a high-level:

- A strategy to drive U.S. innovation and competitiveness through enhanced partnership models with industry, academia, federal and state governments, national laboratories, and regional initiatives, and tighter linkages between those who create technology and those who use it.
- How to redesign federal executive departments and agencies to achieve an integrated and coordinated effort to implement the strategy.

## The Power of a Vision for the Digital Age

Seeing a game-changing opportunity for the United States, in 1993, the Clinton Administration issued *The National Information Infrastructure: Agenda for Action*. It began with a powerful vision—a seamless web of communications networks, computers, databases, and consumer electronics that would unleash an information revolution that would change forever the way people live, work, and interact with each other. It went on to ask Americans to imagine the dramatic changes in their lives if this infrastructure could be realized, offering simple examples of how the ordinary things people do—from getting an education and seeing a doctor, to exploring art and literature or seeing a movie—would be dramatically improved. It described what it would mean for work and business.

Importantly, it explained that “information infrastructure” has an expansive meaning, and that included more than just the physical facilities used to transmit, store, process, and display voice, data, and images. It included a wide range of end user devices, the vast universe of information in many forms that would flow over the infrastructure to the population, and the applications and software that would enable users to access, manipulate, organize, and digest the mass of information that the NII's facilities will put at their fingertips.

The Agenda for Action set forth a series of principles that would guide the Federal action needed to bring this information infrastructure to the United States and the world, recognizing that the private sector would lead deployment. The principles addressed issues such as tax and regulatory policies that promote private sector investment and innovation, user-driven operation, information security, and the protection of intellectual property rights.

- New funding targets for U.S. science and technology, and how the federal government's investment in R&D—beyond federal mission-related and basic research—should align with new domestic and foreign competitive realities, and technological opportunities to best support U.S. economic growth, productivity and inclusive prosperity. This includes technology development, demonstration, application and deployment.
- How the federal government can best support the private sector in ensuring it will provide the United States with the technologies needed for national security.
- What new science and technology infrastructure is needed for increasingly complex, diverse innovation challenges.
- Identification of grand challenges that threaten or would benefit public welfare; how federal government investment or policies can best support the development of technological solutions to these challenges; and how that support should be implemented to ensure a diverse range of Americans can engage in solving the challenges.
- In the context of a free market system, in which not all competitors play by the same rules, how can government best support the gap between research and the application of new technology in industry for developing new products and services.
- How government can best align U.S. policies to create an environment that supports U.S. competitiveness, and the generation of wealth and inclusive prosperity for U.S. citizens in the global economy.
- How the United States can best attract global business investment.
- How to transform education and training in the United States to ensure more of the U.S. workforce has skills to prosper in an economy in which skill demands will shift rapidly in an increasingly technology-intensive work environment.

- How to leverage and expand global partnerships among allies and like-minded nations and carry forward a larger role in an international arena in which technology and innovation issues are increasingly at the heart of long-term competitiveness.

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## RECOMMENDATION

In a parallel effort, U.S. governors and new State Competitiveness and Innovation Councils should engage representatives of the private sector, academia, local governments, and other stakeholders in their State to develop a new State vision and strategy to guide the State's role in science, technology, and innovation. This should include how they will integrate their efforts with the federal and regional innovation initiatives.

## Strategies that Support U.S. Leadership in Critical Technologies

Some technologies emerging today, and undoubtedly they will continue to emerge in the future, will have out-sized transformative effects on industry, economies, global competition, the balance of military power, and society. Today, there are many candidates, but several especially stand out as examples of technologies in which the United States must strive for leadership technologically and competitively in the global marketplace.

### Advanced Computing

Advanced computing must remain central to the United States' current and future competitive advantage in technology and innovation. Capturing the vast economic and national security potential of technologies such as artificial intelligence, biosciences, materials science, the Internet of Things, quantum computing, digital manufacturing, robotics, Big data and cyber security depends on advancements driven by advanced computing—a robust ecosystem across the country of creative and knowledgeable people expertly developing and applying powerful hardware, sophisticated software, and computational methods. As noted in the Council's recent work, *Building University-Industry-Lab Dialogue (BUILD) for High*

*Performance Computing*, advanced computing holds an opportunity to unleash latent innovation potential in the U.S. economy by applying these new tools, perspectives, and resources to existing problems.

Yet, the United States and computing in general sit at a moment in time when advances in generalized computing are slowing, business models surrounding technology investments are changing, and both the public and private sector are searching for ways to continue to push productivity with no clear or reliable technology-specific solution on the horizon.

No current technology in development appears poised to replace the current computing technology paradigm and drive the next generation of advanced computing-driven productivity growth. One of the most significant reasons is that the overall pool of investment in this space is much too small for the challenge—and potential opportunities—at hand. The diversity of potential technology candidates has fractured funding among numerous sources, extending the time for companies to coalesce around a suite of technologies representing next generation hardware and software. In addition, the breadth of the U.S. innovation ecosystem has pushed stakeholders toward increasing levels of specialization, fragmentation, and siloing of many cooperative research efforts.

The United States has significant institutional research capabilities in its national laboratories, many of which are applied to sensitive research related to national security. This places additional barriers and security measures over all work and facilities at the national laboratory enterprise, creating additional hurdles that may discourage potential partnerships with outside entities.

While important to explore all avenues, the timeline being extended by fragmented research efforts and funding that lacks critical mass creates a time-bound economic imperative: Without new, marketable technologies to fund operations at existing fabrication companies, there may be no domestic industry left to compete when technology representing the next S-curve ascends in the market.

Only the federal government has the resources to press continually the frontiers of advanced computing through research and engineering, and those expenditures must be maintained and expanded. It has significant responsibility for this supercomputing critical infrastructure, where leadership at the cutting edge is required to achieve many government missions in areas such as defense, energy, and homeland security. For example, the Department of Homeland Security has identified 19 such areas that benefit from this federal investment and progress in advanced computing. Not only do these advancements support critical government missions, they migrate rapidly into economic strength in the commercial sphere, driving innovations in numerous fields.

Global competitors explicitly state the strategic necessity of computational dominance through data, computational modeling and simulation, and AI, consequently investing aggressively in advanced computing R&D and infrastructure. National security and economic competitiveness will rely upon a computing-augmented workforce for productivity and capability in a world ever-more exhibiting volatility, uncertainty, complexity and ambiguity. The bottom line: advanced computing is a necessity. And its powered by microelectronics.

### **Microelectronics**

Microelectronics—the foundation for the digital age—have been the 20th and early 21st centuries' technological “holy grail.” Digital technologies are now fundamentally integrated into every aspect of human existence, society, and activity—defense, the economy, every industry, health care, education, all aspects of communications, critical infrastructure, transportation, personal living, and more. They are now central to the research enterprise, as laboratory researchers have made a huge shift to digital technology, software, data, and data analytics in their work. The function of the United States and its society are now totally dependent on digital technologies.

## Challenges in Ensuring U.S. Access to Critical Microelectronics

Most commercial off-the-shelf electronics used in U.S. defense systems, U.S. banking, infrastructure, and transportation are produced overseas. And, the global semiconductor industrial capacity is increasingly found outside of the United States. For example, microchips are largely fabricated by three global producers and hard drives by two with factories spread across Asia. While U.S. producers make microprocessors, they send them to Asia for packaging.

The supply of microelectronics to meet U.S. critical needs is at risk for production disruptions, counterfeiting, tampering and insertion of malicious code, intellectual property theft, reverse engineering, and poor quality. Such risks are present along the supply chain—in R&D, design, fabrication and packaging, testing, supply and distribution, storage, and installation. A lack of supply chain custody and security can pose real risk when considering, for example, that a single U.S. Joint Strike Fighter semiconductor component can change hands 15 times before final installation.<sup>i</sup>

i. Microelectronics Risks Throughout the Defense Supply Chain, presentation by Catherine Ortiz, Defense Microelectronics Activity Trusted Foundry Program, October 10, 2017, <https://www.ndtahq.com/wp-content/uploads/2016/04/Ortiz-DMEA-Trusted-Foundry.pdf>

i.i. Semiconductors: U.S. Industry, Global Competition, and Federal Policy, Congressional Research Service, October 26, 2020.

Only three commercial firms—and only one of them U.S.-flagged—produce at the leading edge of microelectronics.<sup>ii</sup> State-of-the-art semiconductor production facilities are likely to dwindle, as the price tag for leading edge fabs stretches to more than \$15 billion, driving the companies to focus on producing microchips for massive commercial markets, with little desire to interrupt this high volume production to serve the high-mix, lower volume microelectronics needs of the U.S. military.

The Federal government has acted before to preserve the strength of U.S. capabilities in microelectronics. Even during a Republican Administration, the threat of semiconductor competition from Japan led to a consensus about the need for an organized U.S. response because of the national security ramifications. Today, the Department of Defense is spending significant sums to bolster U.S.-based microelectronics production.

Digital technologies have been a critical lifeline during the COVID-19 crisis and virus economy—supporting millions of U.S. teleworkers and on-line learners, supporting the on-line purchasing of the homebound population, and the scaling of telehealth—helping prevent the collapse of the economy and maintain social functioning.

Semiconductors are the basic building blocks of other critical technologies such as artificial intelligence, autonomous systems, 5G communications, and quantum computing, and they affect a multitude of products and services of numerous U.S. industries.

The United States remains a global leader in semiconductor R&D, chip design, and some manufacturing. But its position in semiconductor fabrication has been in a long-term decline, from about 40 percent in 1990, to 11 percent of global fabrication capacity in 2019.<sup>40</sup> With production concentrated in East Asia, lack of access to semiconductors due to disruptions such as a trade dispute or military conflict would have severe consequences for the United States and its economy.

40 Semiconductors: U.S. Industry, Global Competition, and Federal Policy, Congressional Research Service, October 26, 2020.

**Figure 6. Consolidation of the Semiconductor Manufacturing Industry**

Source: Intel

2002–2003	2004–2006	2006–2008	2008–2012	2010–2012	2012–2014	2014–2017	Since 2017	Planned
130 nm	90 nm	65 nm	45/40 nm	32/28 nm	22/20 nm	16/14 nm	10 nm	7 nm
<b>25</b>	<b>18</b>	<b>13</b>	<b>13</b>	<b>8</b>	<b>5</b>	<b>4</b>	<b>4</b>	<b>3</b>
Mitsubishi								
Sanyo								
Rohm								
ON								
Hitachi								
Atmel								
ADI								
Sharp	Sharp							
Cypress	Cypress							
Sony	Sony							
Infineon	Infineon							
TI	TI							
Toshiba	Toshiba	TI	TI					
Freescale	Freescale	Toshiba	Toshiba					
SMIC	SMIC	SMIC	SMIC					
Renesas	Renesas	Renesas	Renesas					
Fujitsu	Fujitsu	Fujitsu	Fujitsu					
Panasonic	Panasonic	Panasonic	Panasonic	Panasonic				
UMC	UMC	UMC	UMC	UMC				
ST-M	ST-M	ST-M	ST-M	ST-M				
IBM	IBM	IBM	IBM	IBM	IBM			
AMD	AMD	GF	GF	GF	GF	GF	GF	
Samsung	Samsung	Samsung	Samsung	Samsung	Samsung	Samsung	Samsung	Samsung
TSMC	TSMC	TSMC	TSMC	TSMC	TSMC	TSMC	TSMC	TSMC
Intel	Intel	Intel	Intel	Intel	Intel	Intel	Intel	Intel

Silicon-based microelectronics have advanced along Moore's Law, a pace of development and chip cost reduction that has held true for decades. It asserts that the number of transistors on an integrated circuit would double about every 18 months, creating more powerful and cheaper microchips. However, many believe semiconductors are reaching the physical limitations of silicon and continued development

of more powerful and cheaper silicon-based devices. New approaches to next generation microelectronics will be needed.

Recently, 18 countries of the EU signed a declaration to collaborate on strengthening Europe's capabilities to design and eventually fabricate the next generation of low-power semiconductors for various

applications, and to bolster the whole electronics and embedded systems value chain.<sup>41</sup> The EU is expected to invest up to \$145 billion in this initiative.<sup>42</sup> China has already revealed plans to devote \$150 billion in semiconductor research and acquisitions to build out a Chinese microelectronics value chain.

Continued leadership in microelectronics technology, and assured access to the supply chains that provide them and the personnel to manage them will be essential for the United States to maintain its position as a world economic and military leader, and as the most prolific innovating nation.

### Biotechnology

As the costs of gene-sequencing continues to fall faster than Moore's Law, and as it converges with powerful computing, automation, and artificial intelligence technologies, biotechnologies have transformative potential. A recent study suggests as much as 60 percent of the physical inputs to the global economy could be produced biologically—one-third biological materials, and two thirds produced using biological processes, for example bioplastics. These applications alone could have a direct economic impact of up to \$4 trillion a year over the next 10-20 years. The study also suggests that 45 percent of the world's current disease burden could be addressed with science conceivable today. However, these technologies pose unique risks, with the potential for unintended consequences, malicious and unethical use, and invasions to privacy.<sup>43</sup>

Researchers and industry are fueling the bioeconomy with genomic knowledge derived from sequencing only a tiny fraction—0.3 percent—of the estimated 1.8 million species of Eukaryotes—plants, animals, and microbes with nucleated cells. Sequenced genomes of these microbes, plants and animals would provide key elements of the biological infra-

structure to undergird the expansion of the bioeconomy by providing the knowledge and resources for new medicines, energy, and food. Other nations recognize this potential and are investing heavily in the sequencing of genomes. For example, China is taking aim at leadership in biotechnology, and now accounts for 30 percent of the world's sequencing capacity.<sup>44</sup> The United States has led the biotechnology revolution since the human genome was sequenced and should ensure its continued global competitive leadership by leading, for example, a major U.S. effort to sequence the genomes of all species of Eukaryotes.

### Nanotechnology

Nanotechnology is beginning to enable a world of new materials designed at the atomic and molecular scale—gases, liquids, and solids with novel and beneficial chemical, physical, mechanical, optical, and biological properties. It has the potential for breakthroughs in many fields such as medicine, imaging, computing, printing, chemical catalysis, materials synthesis, energy, environmental remediation, transportation, and others. A wide range of nano-enhanced everyday products are already on the market—such as electronics, fabrics, sports equipment, batteries, paints, and lubricants—and many more will emerge in the years ahead.

### Quantum

Quantum information science (QIS) combines elements of mathematics, computer science, engineering, and physical sciences, and has the potential to provide capabilities far beyond what is possible with the most advanced technologies available today. There are three key areas of application for quantum: computing and simulation, communications, and sensing and metrology. Quantum computers could revolutionize computation by solving previously unsolvable problems. There are certain tasks for which the power of quantum computing is unmatched, such as code breaking. Quantum computing could be a game-changer in medicine, encryption, chemistry, the development of new

41 Declaration, European Initiative on Processors and Semiconductor Technologies, December 7, 2020.

42 Week in Review, Manufacturing, Test, Semiconductor Engineering, December 11, 2020.

43 The Bio Revolution: Innovations Transforming Economies, Societies, and Our Lives, McKinsey Global Institute, May 2020.

44 2018 Global R&D Funding Forecast, R&D Magazine, Winter 2018.

## Nanotechnology: Large Potential for Innovation in a Small World

Source: nano.gov

Water repellent coatings and surfaces

Stain proof clothing

Antimicrobial surfaces

Invisibility cloak

Sensors on a tape for plants

Lab-on-a-chip

Drug delivery directly to cancer cells

Nanoribbons to help repair spinal cord injuries

Sensor to tell you when fruit is ripe

Food safety monitoring

Nanocrystals that protect plants from frost

Sensing machines that operate inside living systems

Ultra-sensitive chem/bio detectors

Oil cleaning sponge absorbs 100 times its weight

Film membranes for water desalination

Low cost water purification

Flexible, bendable, foldable, rollable electronics

Self-healing, mark and scuff-resistant paint

Self-cleaning windows

Scratch resistant glass

Artificial muscle and cartilage

Paper-thin wearable loudspeaker

Transparent wood that can stop a bullet

Clothing that harvests energy through movement

materials, communications, artificial intelligence, and other fields involving complex problems and systems. Quantum computing could mature just as we reach the physical limits of silicon technology for semiconductors and reach the end of Moore's Law—the running rule that computer chips would steadily get more powerful.

Quantum research is being pursued at major research centers around the world. The United States has increased its investment. While China and the EU have the largest foreign quantum information science programs, many other countries—including Canada, Russia, Germany, and Australia—are making strides in quantum R&D. Recently, China claimed it has made a critical breakthrough—building a prototype quantum computer that researchers say took 200 seconds to provide a calculation that would have taken a regular supercomputer 2.5 billion years to carry out.<sup>45</sup> The quantum race is on—as in

2019, Google achieved quantum supremacy with a 53-qubit processor performing a certain computation within 200 seconds (a task that Google estimated would have taken the world's most powerful supercomputer 10,000 years).<sup>46</sup> U.S. economic and national security depends on the United States staying ahead in the game.

### Artificial Intelligence (AI)

Artificial intelligence is likely to be a defining, apex technology of the next 50 years—expected to be deployed and drive a massive transformation in: all aspects of global commerce and business operations, military systems, transportation, health care, education, research and development, infrastructure and energy systems, agriculture, decision-making, the management of cities and transportation, harvesting and managing knowledge from the exponentially growing data universe, and in a wide range of human support systems. And while digital technolo-

45 Chinese Photonic Quantum Computer Demonstrates Quantum Supremacy, Physics.org, December 4, 2020.

46 <https://newatlas.com/computers/jiuzhang-chinese-quantum-computer-supremacy/>.

gies are merging the physical and virtual worlds, AI will make them intelligent. The United States must continue to advance and scale the current “second wave” of AI, such as machine learning and big data, but also increase its investment and research to secure U.S. leadership in the next generation “third wave” of AI, for example, in artificial cognition, sense-making, and human-machine interfaces.

### Industrialization of Space

The door to the industrialization of space is opening wider, and efforts to leverage the commercial opportunities in space are accelerating. The recent crewed mission to the International Space Station aboard a privately built and launched spacecraft signaled a new era of private space industrialization, and private investment in commercial space activity is growing. The efforts of bold entrepreneurs and others are leading to breakthroughs in cost, efficiency, and creative solutions across the space field. While commercial space is in its infancy, currently, commercial ventures represent about 80 percent of the global space economy's more than \$400 billion value.<sup>47</sup> The U.S. space workforce has grown to 184,000 in core-employment (2019), along with a record \$5.8 billion of capital directed at new space products and services. More than 70 percent of this 2019 investment was sourced from venture capital.<sup>48</sup>

The United States is a leader in commercial space, the first nation to demonstrate commercial orbital cargo delivery, commercial heavy lift, commercial first-stage reusability, deployment of space-based mega-constellations for overhead sensing, internet broadband, and commercial human spaceflight. Morgan Stanley projects that global space industry revenues could grow to \$1 trillion or more by 2040.<sup>49</sup> In the nearer term, there is interest in satellite broad-

band, overhead sensing, space information services such as resource mapping, and human space travel. In the longer term, visionary entrepreneurs see a future of manufacturing in space, mineral mining on asteroids and the moon, space-based solar power, and colonization of Mars. China is committed to become the leading, global superpower by 2049. A key component of China's strategy is to displace the United States as the leading power in space, and lure U.S. allies and partners away from U.S.-led space initiatives.

### Hypersonics/Advanced Aerospace Technologies

Aerospace technologies have provided the U.S. military with a critical advantage in global persistent awareness, speed, and reach. The United States must keep pace as new technological opportunities emerge in areas such as small satellites and low-cost launch, low-cost air and space platforms; low cost, network cruise missiles and smart munitions; and scramjet propulsion.

For example, with the potential to be as transformational as supersonic flight, systems that operate at hypersonic speeds—five times the speed of sound (Mach 5) and beyond—offer the potential for military operations from longer ranges with shorter response times and enhanced effectiveness compared to current military systems. These include hypersonic glide vehicles launched from a rocket, and hypersonic cruise missiles powered by high-speed, air-breathing engines. Due to their speed, maneuverability, and low altitude of flight, hypersonic weapons could be defense game changers, potentially shifting the balance of global military power. Terrestrial-based radar cannot detect them until late in their flight, significantly reducing the time decision-makers have to determine their origin, assess their options for response, and for a defensive weapon to intercept the attacker.<sup>50</sup> In addition to the United States, China and Russia have made the development and testing of hypersonics a high priority and have advanced programs. Other nations developing hypersonic

47 <https://www.commerce.gov/news/speeches/2020/10/remarks-commerce-secretary-wilbur-l-ross-grand-opening-astrobotic-technology>.

48 State of the Space Industrial Base 2020: A Time for Action to Sustain U.S. Economic & Military Leadership in Space, Summary Report by: Brigadier General Steven J. Butow, Defense Innovation Unit; Dr. Thomas Cooley, Air Force Research Laboratory; Colonel Eric Felt, Air Force Research Laboratory; Dr. Joel B. Mozer, United States Space Force, July 2020.

49 Space: Investing in the Final Frontier, Morgan Stanley, July 24, 2020.

50 Hypersonic Weapons: Background and Issues for Congress, Congressional Research Service, December 1, 2020.

weapons technology include Australia, India, France, Germany, and Japan; Iran, Israel, and South Korea have conducted foundational research.<sup>51</sup> In the future, commercial flight using hypersonic technology may be possible.

### Advanced Manufacturing

Rapid advances in technology—as well as in market, competitive, and economic forces—are changing the ways products are conceived, designed, made, distributed, and supported. In the past few decades, global competition in manufacturing—including competition from low-wage developing countries—has driven the maturation and commoditization of manufacturing, and the widespread application of digital technologies in manufacturing and logistics has leveled the global technological playing field.

However, pervasive networking and recent advances in machine learning, biotechnology, and materials science are creating new opportunities to compete in manufacturing based on scientific and technological innovation. For example, digital design and manufacturing seamlessly distributes the information needed to transform designs and raw materials into products, resulting in a highly connected industrial enterprise that can span multiple companies within a supply chain. Smart manufacturing enables the execution of that transformation by sensing and correcting anomalies to ensure product uniformity, quality, and traceability. These advances depend on the innovation of a robust industrial Internet of Things, machine learning algorithms that can be applied across a broad range of manufacturing processes, and machine tools and controllers that can plug-and-play in an integrated, information-intensive system.<sup>52</sup>

The convergence of cloud computing, data analytics, and computational modeling with artificial intelligence will be a key enabler of the industrial Internet of Things, allowing individual manufacturers to extract guidance from the collective experience

of every manufacturer. This vast store of experience captured in datasets will increase in power as more data is accumulated and made available, and as machine learning and artificial intelligence mine and pinpoint relevant information and solutions.

Collaborative teaming of humans and smart robots will decrease the mental and physical stress on workers, reduce manufacturing costs, increase quality, and provide quick response to changing customer demands. Advanced robotic systems that are flexible and perform multiple tasks will reduce capital investment and increase manufacturing agility by eliminating the need for several special-purpose tools. Robot-based production systems can also enable efficient batch-of-one production for mass customization.

The United States leads the world in scientific and technological innovation. It must protect and leverage this strength by rapidly and efficiently developing and transitioning new manufacturing technologies into practice within our domestic industrial base.

As the United States must have a strong advanced manufacturing base, the COVID-19 pandemic demonstrated the critical need for strong and responsive supply chains that support production. The pandemic exposed U.S. weaknesses and failures of key supply chains under surging demand, lack of control over segments of the supply chain for critical health care products, and reliance on China for critical U.S. needs. In an April 2020 speech, Chinese President Xi Jinping said that China must tighten international production chains' dependence on China, to form a powerful countermeasure and deterrent capabilities based on artificially cutting off supply to foreigners.<sup>53</sup>

The United States' supply chain challenges extend to critical areas of innovation and technology needed for national defense, economic security, and health care including life-saving pharmaceuticals, critical

51 Hypersonic Weapons: Background and Issues for Congress, Congressional Research Service, December 1, 2020.

52 Strategy for American Leadership in Advanced Manufacturing, National Science and Technology Council, October 2018.

53 Certain Major Issues for Our national Medium- to Long-Term Economic and Social Development Strategy, speech given by Chinese President Xi Jinping in April 2020, translated by Etcetera Language Group and Center for Security and Emerging Technology, Georgetown University, November 10, 2020.

rare earth minerals and materials, and the microelectronics on which the U.S. economy and society is now totally dependent.

### The Disruptors

These technologies, platforms and the innovations emerging from their deployment in society will shape the global economy for decades to come. They are disrupting industries around the globe and altering many dimensions of our lives. They present vast opportunities for innovations that can drive economic growth, job creation, and higher living standards for every American, as well as provide solutions to many of the global societal challenges we face in health, energy, food production, clean water, and sustainability.

Recognizing the importance and power of emerging critical technologies, some nations have adopted strategies focused on research, technology development, and deployment of one or more critical technologies. For example, China's state-led efforts to develop a domestic integrated semiconductor industry are unprecedented in scope and scale. Should China succeed, significant global semiconductor production, design, and research capabilities could shift to China, undermining the U.S. position and putting an assured supply of microchips at risk. Similarly, China's New Generation of Artificial Intelligence Development Plan is a blueprint for constructing an AI innovation ecosystem that they believe will make China the world's AI leader by 2030. A wide range of other nations have adopted strategic plans in areas such as biotechnology and nanotechnology, among others.

To control its economic destiny and national security, the United States must have a strong position, if not globally unparalleled strength, in these technologies.

### Historical Perspective: Critical Technology Strategy for Superconductivity

Motivated by exciting developments in the quest for room temperature superconducting materials, in 1987, President Reagan issued an 11 point plan that went beyond R&D to move scientific achievements more rapidly into the commercial realm:

- Proposed to amend the National Cooperative Research Act of 1984 to permit joint production ventures
- Proposed to amend patent laws to increase process patent protection
- Proposed to exempt commercially valuable information developed at Federal laboratories from disclosure under the Freedom of Information Act
- Establish a President's Advisory Council on Superconductivity
- Establish Superconductivity Research Centers at Federal laboratories
- Accelerate implementation of Federal technology transfer laws
- Accelerate processing of patent applications
- Accelerate standards development
- Shift funds into superconductivity R&D
- Accelerate military development of electronics and sensor applications
- Seek opportunities to participate in joint R&D programs with Japan

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## RECOMMENDATION

The federal government—in partnership with industry, the academic sector, and other stakeholders—should develop national critical technologies strategies for those technologies in which the United States must have a leading global position. For each critical technology, these strategies should include a whole-of-nation effort guided by:

- Plan for public R&D spending that complements industry investment and provides funding in key elements of the innovation process that will accelerate and smooth technology development, commercialization, scaling and deployment, including the valley of death, demonstration, and scientific or technological infrastructure.
- A technology roadmap to help focus public and private R&D investment.
- Plans to accelerate the development of needed regulations and policies.
- Plan to accelerate standards development.
- Plans to ensure the United States has a workforce with the skills to develop and leverage these technologies and their manufacturing, including ensuring it diversity and inclusivity, and to support and redeploy workers who are displaced by the scaling of new technologies.
- Plans to establish initiatives, programs, or centers to accelerate the domestic deployment of these technologies.
- Identification of financial and tax incentives to be enacted to encourage the establishment of U.S. domestic production and supply chains in these technologies.
- Plan for creating a focus on the technology in efforts around the country, for example state and regional efforts, working to stimulate entrepreneurship, new business formation, and growth.
- Plan for promoting U.S. products and services based on these technologies in global markets.
- Identification and plan to address domestic social, ethical, and environmental issues associated with the technology, and to advocate for U.S. positions in bi-lateral and multi-lateral agreements that address these technologies.
- Plans for action to mitigate efforts to raise barriers to U.S. products and services based on these technologies in other countries, and to enforce existing trade laws in areas such as targeted subsidies, forced technology transfers, non-reciprocal tariffs, etc.
- Process for identifying the emergence of technologies that warrant government attention because of their criticality to U.S. national and economic security.

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## RECOMMENDATION

The United States should seek to secure supply chains with a high degree of criticality to its economy, national defense, and public health.

- In an effort led by the new National Innovation and Competitive Council, the federal government—including the Departments of Defense, Homeland Security, Commerce, Energy, and Health and Human Resources, and the intelligence community—should identify which links in U.S. supply chains are essential to keep under U.S. control now, and also those with the capabilities and capacities needed for future critical innovations.
- Consider repatriating U.S. supply chains for critical supplies such as medical equipment, medical supplies, medicine and medicine precursors; critical minerals and materials; and products needed to secure food and national security.
- Establish incentives—such as tax and regulatory incentives—to help mitigate and lower the risk of repatriating companies and their supply chains, especially those with critical technologies, back to the United States. Socializing this risk is justified because these critical technologies underpin national security and civilian social needs, such as in health care, education, and the conduct of science, in addition to their commercial uses.

- Companies should build greater resiliency into their supply chain through greater flexibility, geographic diversity, and depth in suppliers (and beyond first tier).

## Creating a Capability for Competitiveness and Innovation Intelligence and Indicators

### Understanding the Competition

U.S. competitors around the world seek to build and strengthen knowledge and technology-based economies as the basis for advancing productivity, job creation, raising standards of living and, in some cases, geopolitical goals. As a result, many deploy policies and programs to harness science, technology, and innovation, and to create a business environment to achieve this impact. These include a broad and diverse range of efforts—R&D investments, national research programs, tax incentives, science and research parks, national science and technology strategic plans, high-level leadership organizations, efforts to target industry clusters, demonstration projects, state subsidies, grant programs, national goals, and more. These countries are instituting their own distinctive innovation ecosystems, which may not be compatible or friendly with U.S. systems of innovation.

The U.S. military and intelligence community monitor and assesses the capabilities and moves of potential U.S. adversaries, including their use of new technologies in military systems. As technology is now fundamental to U.S. economic security, the importance of understanding the goals, capabilities, and moves of our global technology and market competitors is essential. However, the federal government does not systematically collect, analyze, or publish data and information on the investments, policies, and programs of other nations designed to strengthen their competitive position and build their innovation capacity. As other nations' capabilities rise, and they target the same technologies and markets as the United States, it is critical to better understand their efforts and the impact on our own, what we can learn to apply to the design and operation of U.S. technology

and innovation initiatives, and to get “early warning” of risks from a strengthening competitor. The bottom-line: the United States needs better “innovation radar.”

### Gauging U.S. Performance

Historically, the United States has gauged its capacity for innovation through a largely input-oriented model that focuses on, for example, investments in research and technology, and the overall business environment, and outputs such as patents or scientific papers. U.S. policies, programs, and investments traditionally focus on strengthening these input “pillars.”

However, innovation drives economic growth through a dynamic process of: creating and synthesizing new knowledge, and inventing new technologies, products and services; commercializing the new knowledge, products, and services; and deploying and scaling what has been commercialized, and the resulting reorganization of markets, business and industrial sectors, supply chains, and the economy. There are numerous factors that affect the health and performance of this growth engine. And while historic attention has been paid to the input side of the innovation equation, over the past several decades, greater attention has been given to commercialization, new business formation, and technology transfer from universities and federal labs, including federal patent licenses to industry.

Less attention, however, has been given to the deployment and scaling of new technologies and innovations, and the resulting reorganization of markets, business and industry, labor markets, and the economy. Yet, here is where the most jobs, economic growth, and wealth creation occurs—by far.

Like a multi-point car inspection/diagnostic test or a health screening, today, there are numerous data collected that the United States could use to develop a portfolio of indicators that, taken together, would provide significant insight on the health and performance of the U.S. innovation system. And, in some cases, data would be available to make comparisons with major U.S. competitors.



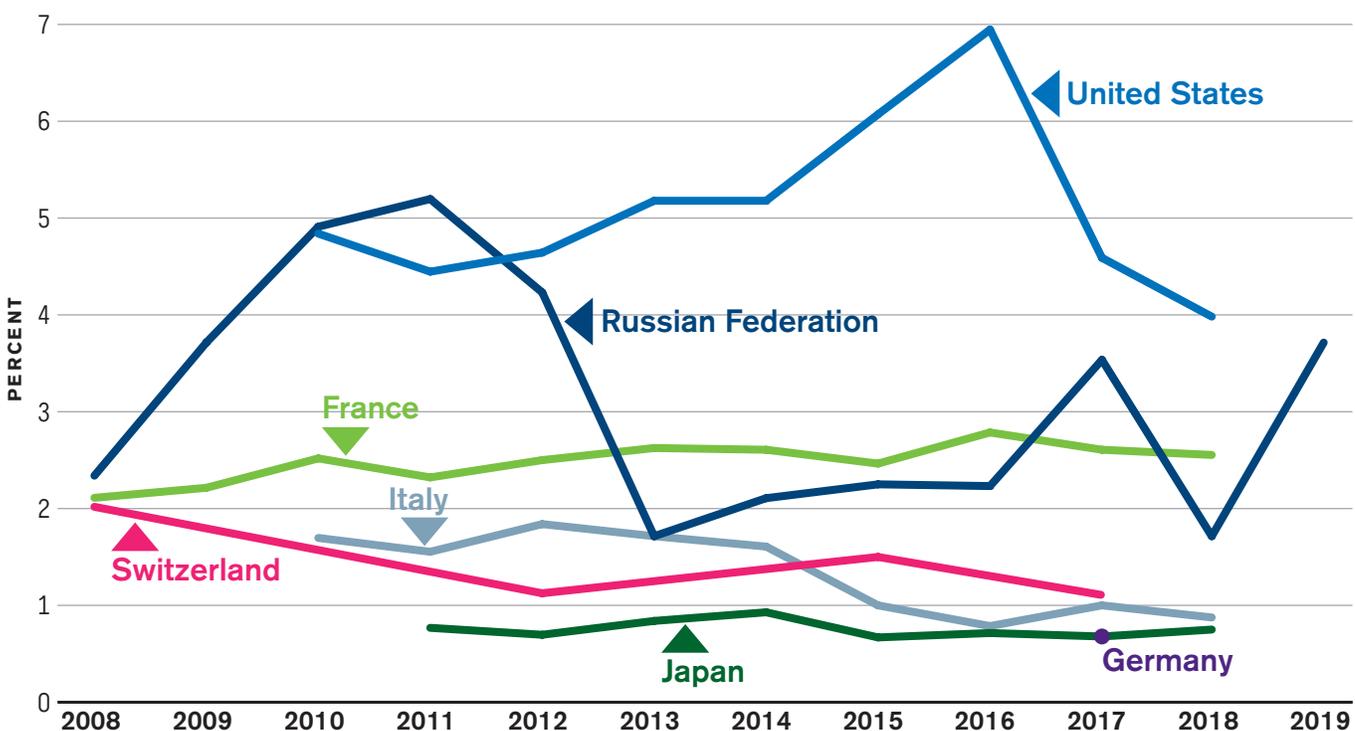
- Conduct special “deep dive” studies to provide further insight on the U.S. position, its strengths, weaknesses, and vulnerabilities.
- Assess U.S. global competitors along a continuum of competitive strength, including a view from a critical industry and critical technology perspective. In addition to the current competitive situation, create an early warning capability to signal and monitor competitor strengthening and capabilities-building that could be realized in the decade ahead, and potentially challenge the United States in critical emerging technologies and innovations of importance. The goal would be to prompt the United States to take steps to ensure it is not over-matched in the future.
- Drawing on data already collected and published, from both U.S. sources and foreign data collectors such as the OECD, identify, collect, and create a publicly available dashboard based on a core set of indicators focused on creating new knowledge and inventing, technology and innovation commercialization, and scaling and economic reorganization such as industry growth and labor market shifts.
- In key areas of interest—for example, in microelectronics, artificial intelligence, or robot deployment—develop and track a set of indicators such as public R&D investment, venture capital investment, new business formation, job growth or loss, etc.—to monitor the U.S. position in these technologies, and those of key U.S. competitors, and the effectiveness of actions to improve U.S. competitiveness. Use any signals to trigger further study or the need to shift or modify U.S. actions or programming.

## RECOMMENDATION

Develop a dynamic innovation decision dashboard, based on the findings of the innovation radar, to support scenario development, decision-making, policy development, and action.

**Figure 8. Nanotechnology R&D as a percentage of BERD, 2008-18**

Source: OECD, Key Nanotechnology Indicators, <http://oe.cd/kni>; and OECD, Main Science and Technology Indicators Database, [www.oecd.org/sti/msti.htm](http://www.oecd.org/sti/msti.htm), October 2020.



## Establishing a New Technology Statecraft to Strengthen Advocacy and Action for U.S. Technology and Competitiveness Interests in the International Arena

America's long-term position and influence in the world will be determined by its technological capabilities and their application. U.S. global competitive strength in advanced technologies can be significantly enhanced by the exercise of American influence through international economic, scientific, and security institutions and arrangements.

After World War II, the United States actively sought internationally to create rules, arrangements, and institutions aligned with American values and interests. In this effort, the United States had the support of, and worked collaboratively with, leading liberal democracies and market economies, and, at the same time, sought more broadly to incorporate other nations into these arrangements.

However, there has been a recent diminution in U.S. international engagement and leadership within international institutions where the United States once played the leading role. Some of these institutions play key roles in shaping the 21st century economy with implications for American competitiveness. With a vacuum created, China has moved aggressively to assert itself, assume leadership roles, and shape from the inside the future direction of many of these institutions.

For example, in some areas, China has created parallel institutions more amenable to its priorities such as the Asian Infrastructure Investment Bank (AIIB), enabling China to play a greater role in economic development in Asia. The AIIB and other Chinese financing programs are creating economic dependency in many emerging markets, which can shift the political orientation and values of these countries—with geo-political implications for the United States, including the market access necessary for scaling and the financial viability of commercializing technology, raising the risk of intellectual property theft, and potentially increasing the cost of cyber security.

## Technology Statecraft

The integration of decision-making, policy action, deployment of resources, diplomacy, and advocacy to advance the objectives of American global preeminence in critical technologies and associated innovations, national security, economic growth, and inclusive prosperity.

China's strategic ambition to reach the commanding heights of technology drives its moves in the international arena and creates the context for the provision of domestic resources and a favorable regulatory environment to develop high-technology state champions (companies). To achieve these objectives, it employs tactics such as extensive subsidies to support R&D, subsidized export financing, easy non-compliant infrastructure financing, theft or forced technology transfer, and market access limitations to protect nascent domestic technology industry development.

The United States and its allies have built strong global institutions undergirding the post-World War II order, but their influence has atrophied with the rise of other powers and growing American isolationist trends. At the same time, large areas of state behavior involving critical technologies remain outside existing rules, institutions, and international standards; these behaviors will be unconstrained unless rules are written. A leadership vacuum in these institutions permits opposing norms and values to assert themselves and undermine long-standing international standards of behavior and practice. These institutions are in place and hold valuable assets and expertise, but many are in need of reform and new mandates of relevance.

## RECOMMENDATION

The United States should place technology statecraft at the forefront of its economic and national security strategy in the international arena. This includes U.S. government actions focused on international rules, institutions, arrangements, deployment of capital and scientific resources, and mutually-beneficial collaboration with private companies and like-minded sovereigns and foreign partners that share American values and interests in shaping rules for the 21st century economy. The United States should seek to counter-balance the Communist Party of China's active role in reforming the global governance system and a future shaped by its values and interests, and its aggressive moves into world power structures and capture seats in international deliberative bodies.

The United States must play a more muscular role in the following high priority international economic, trade, scientific and technology related institutions, venues, agreements and arrangement that will play a key role in shaping the 21st century economy and, as a result, potentially affect U.S. global competitiveness:

- Institutions with jurisdiction on flows of good, services, capital, and data:** This includes the World Trade Organization, the Organization for Economic Cooperation and Development, World Bank, Financial Stability Board, Bank for International Settlements, G20, G7, and regional multilateral development banks. These institutions are rule-writers and standard-setters, but currently a patchwork of bilateral, plurilateral, and multilateral efforts with no central direction, and advanced liberal economy engagement is weakening. The United States and its advanced nation friends and allies have control—if they act in coordination.
  - New rules for the digital economy:** The free flow of data has been critical to the continued growth of digital trade and U.S. competitiveness in the digital revolution. However, multilateral rules reflecting U.S. interests and values need to be developed but remain at a standstill today. The United States plays an important role in international discussions on data protection and
- has begun to address data privacy and data flows in free trade agreements, including in the U.S.-Mexico-Canada Agreement. But, with no multilateral rules on cross-border data flows, the EU's General Data Protection Regulation (GDPR) may effectively set new global data privacy standards, as firms and organizations strive for compliance to avoid being shut out of the EU market or penalized, and as other countries seek to introduce rules modeled on the GDPR. Such developments could limit U.S. influence in trade negotiations, such as in the ongoing World Trade Organization plurilateral negotiations related to e-commerce.
- Areas of priority include e-commerce, digital flows (free flow of information, limits on localization requirements, privacy, limits on censorship, and cyber security), enforcement of intellectual property rights, and central bank digital currency. China wants to write these rules, and its accelerating advancement in critical technologies will enable its influence in these efforts.
- Institutional Reform:** With limited support from major members, the credibility of the World Trade Organization is at a low point. The United States should join with Japan, the EU, South Korea, Australia, and others and press institutional reform as a predicate to more active new multilateral rule negotiation. Also, the United States should join the Comprehensive and Progressive Agreement for the Trans-Pacific Partnership to advocate for and support liberal economy rule-writing.
  - Capital Flows:** By and large, cross border capital flows are not regulated, lack cross-border standards, and transparency is weak. Cross-border controls skew market functioning, and investment-related international standards are limited; for example, there are no broad-based World Trade Organization or OCED agreements.
  - Rules Related to Infrastructure Financing and Procurement:** China's behavior has undermined international standards to the point where no standards channel behavior, particularly with respect to the transportation, energy, and communications sectors, and extend to China's

## Digital Data

The EU's sweeping General Data Protection Regulation restricts the transfer of the personal data of EU citizens outside of the EU, except to specific countries that the EU has determined provide adequate data protection under EU law or when other specific requirements are met, such as the use of standard contract clauses or binding corporate rules. Restrictions on the flow of data have a significant effect on conditions for the cross-border supply of numerous services and for support to the functionality embedded in intelligent goods (i.e., smart devices). Under the GDPR, which took effect on May 25, 2018, fines of up to four percent of annual global revenue can be imposed on firms that breach the new data protection rules. For multinational corporations, such fines could amount to billions of dollars.

GDPR put some of America's most globally successful and innovative companies into the cross-hairs—Apple, Amazon, Google, Facebook, Netflix, and Twitter—companies with data at the core of their business. The day the GDPR went into effect, complaints were filed against Google and Facebook, as well as WhatsApp and Instagram which are owned by Facebook. All of these companies are under investigation or scrutiny in the context of this regulation. Numerous U.S. news web sites and digital advertising firms withdrew from the EU market finding it too cumbersome and too costly to comply.

The EU hopes the GDPR will further develop the EU's Digital Single Market, aimed at increasing harmonization across the bloc on digital policies. The EU also views the GDPR as underpinning efforts to bolster the EU's technology sector vis-à-vis Chinese and U.S. competitors.

The GDPR creates liability for controllers (the entity that determines the purpose and means for processing personal data) and processors (generally contractors hired to process personal data on behalf of the controller). The regulation requires companies to have a data protection officer or representative present in the EU. It adds new requirements for accountability, data governance, and notification of a data breach. In addition, the GDPR provides expanded rights to EU data subjects, including data portability, more stringent consent requirements, and the right for EU citizens to demand that search engines remove information that is inaccurate, inadequate, irrelevant, or excessive for the purposes of data processing.

U.S. firms have voiced several concerns about the GDPR, including the need to construct a compliance bureaucracy and possible high costs for adhering to the GDPR's requirements. While large firms have the resources to hire consultants and lawyers, it may be harder and costlier for small and mid-sized enterprises to comply, possibly deterring them from entering the EU market and creating a de facto trade barrier. Some industry surveys show that GDPR's restrictions on the use and sharing of data may be limiting the development of new technologies and deterring potential mergers and acquisitions.

Digital Silk Road initiative for digital connectivity. China is the world's largest infrastructure development bank, providing more financing than the World Bank and regional development banks combined, and operates in large degree outside World Bank and OECD standards.

- **Regulatory Actions that Affect Competition:** In the areas of subsidies, tax mandates, antitrust, and controls on competition, there is limited agreement on rules and, thus, little domestic constraint on seeking advantage for domestic champions within the home market and providing artificial advantage in global markets. Common approaches on antitrust and competition policy may need to be pursued outside traditional institutions and instead pursued on an issue specific basis among like-minded sovereigns.
- **International Scientific Institutions:** Personnel is policy: 4 of the 15 UN specialized scientific- and technology-related agencies are now led by China—International Telecommunications Union, the International Civil Aviation Organization, the United Nations Industrial Development Organization, and the Food and Agriculture Organization. In contrast, the United States leads one. China also gives priority to the World Health Organization, the World Intellectual Property Organization, the International Atomic Energy Agency, and Interpol. It also holds senior positions in the leading international financial institutions and multilateral development banks. Slowly, but surely, China is expanding its position for much greater influence over the institutional order.

Common action among the advanced liberal economies is needed to counter-balance China's moves to capture these institutions. For example, the United States led an effort to mobilize key allies in countries that rely on or aspire to have intellectual property as a major driver for their economies to support Singapore's Daren Tang as Director General of the World Intellectual Property Organization, denying China—perhaps the world's greatest infringer of intellectual property—leadership of the international guardian institution for intellectual property. The United States needs to focus on agenda setting within these

scientific institutions, make personnel a priority, link policy with funding, set high expectations for transparency and disclosure, insist on independent investigations as to internal workings, and make institutional reform a priority.

- **International Standard-Setting Processes:** China intends to become a significant player in international standards setting—especially for next generation technology—and is increasing its profile in international standards development organizations.<sup>54</sup> Its efforts are well-resourced, state-led, and strategic, viewed as an integral part of international competition. For example, it is set to release *China Standards 2035*, an industrial plan aimed at strengthening the development of next generation technology standards and influencing standards setting in emerging technology fields such as integrated circuit design, Internet of Things, cloud computing, big data, 5G, intelligent health care, photovoltaics, and artificial intelligence.<sup>55</sup>

In May 2020, China's National Standardization Committee released the *Main Points of National Standardization Work*. The *Main Points* report emphasizes expanding China's role in international standards bodies, including establishment of new international standards technical institutes, and enhancing China's ability to assume responsibility for the technical bodies of the international standards organizations. *Main Points* mentions developing and promoting standards for technologies such as blockchain, quantum computing, intelligent manufacturing, smart and electric vehicles, energy storage, smart cities, virtual reality, bio-based products and materials, and others.

China advances its role in standards setting through its leadership and participation in the International Standards Organization, the International Electrotechnical Commission, International Telecommunications Union, and

54 China-Standards for Trade, International Trade Administration, U.S. Department of Commerce.

55 <http://www.cnstandards.net/wp-content/uploads/2019/03/China-Standard-2035.pdf>.

various technical committees; bilateral cooperation agreements; and through Belt and Road Initiative Memoranda of Understanding. In addition, the gravitational pull of China's market acts as de facto means of standards diffusion.

In the United States, the private sector leads standards development. Nevertheless, the United States should become more coordinated in its standards agenda setting, facilitated by a larger federal leadership role, to ensure U.S. efforts are well-resourced, that the United States can build capacity abroad, that U.S. industry is pro-active in its participation, with no vacuum in personnel.

- **International Coordination on Controls Related to Cross-Border Transfer of Critical Technologies:** The global diffusion of technology imposes limitations on the effectiveness of unilateral U.S. controls of critical technologies. Analogies to a COCOM-type regime (a multi-lateral control arrangement) among close U.S. allies has been suggested and is important to the effectiveness of controls and sanctions. Also, coordination among allies becomes more urgent as U.S. unilateral reach over financial transactions will likely be challenged by crypto-currencies or blockchain technologies.

The Foreign Investment Risk Review Modernization Act of 2018 (FIRRMA) expands the U.S. government's authority under the Committee on Foreign Investment in the United States (CFIUS) to review investment transactions—whether or not they convey a controlling equity interest—where a foreign person has access to information, certain rights, or involvement in the decision-making of certain U.S. businesses involved in critical technologies. FIRRMA also allows CFIUS to discriminate among foreign investors by country of origin by labeling some as “a country of special concern” that has a demonstrated or declared strategic goal of acquiring a type of critical technology that would affect U.S. leadership in areas related to national security. However, the U.S. government has been slow to implement these new authorities.

- **International Coordination on Investment Review on National Security Grounds:**

Diffusion of technology globally underscores the importance of coordinated standards among advanced liberal economy countries related to review of greenfield investment and acquisition by certain foreign actors, particularly state-sponsored entities. The need for such coordination is heightened by adversary tactics of seeking to conceal through complicated ownership structures the true parties behind an investment. Joined with this is the need for greater advanced country consensus on investment-related disclosures and transparency.

- **A New U.S. Technology Statecraft Team**

Reassuming a strong American leadership presence in an international policy arena increasingly shaped by technology requires the United States to integrate science, technology, and innovation into our core diplomatic and foreign service capability. China already integrates and works to achieve its national science, technology goals as its personnel carry out its foreign political, national security, and commercial engagements with other countries around the world.

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## RECOMMENDATION

The United States should establish an International Science, Technology, and Innovation Corps, increasing 10x: the number of Americans with backgrounds in science, technology, and innovation serving in the diplomatic corps as foreign service officers, in the Foreign and Commerce Service, and as trade negotiators; and representatives from academia and business, and technology leaders engaged in international organizations such as the United Nations Industrial Development Organization, United Nations Conference on Trade and Development, and others.

## Guidelines and Policies for U.S. Participation in International Collaboration in Research and Development, and Global Science, Technology, and Innovation Initiatives

As science and technology have globalized, as other nations have raised their science and technology capabilities and launched R&D and innovation initiatives, and as global challenges increasingly call for multilateral collaboration, opportunities for U.S. participation in international R&D partnerships and initiatives have increased significantly. For example, the United States participates in nearly 60 bilateral science and technology agreements, and more than 2,000 sub-agreements. These engagements can advance U.S. opportunities to develop and commercialize cutting-edge technologies, as well as position the United States to develop and capitalize on solutions to global challenges in areas such as health, cleaner energy, the environment, adequate food, and clean water.

At the same time, however, China seeks to extract U.S. intellectual property, science and technology to enhance its own capabilities and undercut U.S. leadership. This includes engaging U.S. researchers in joint research and partnering with U.S. universities in establishing research centers and joint initiatives. For example, in 2018, 39 percent of U.S. science and engineering articles were developed through international collaboration, up from 19 percent in 2000. U.S. authors collaborated most frequently with authors from China (about 26 percent of U.S. internationally coauthored articles in 2018).<sup>56</sup> China has also used illicit means to acquire U.S. intellectual property, and some U.S. researchers have participated in Chinese talent programs, without reporting their involvement when applying for federal research grants. A significant portion of basic research is supported by U.S. taxpayers.

U.S. participation in international science and technology research, partnerships, and initiatives should be mutually beneficial, involve balanced contributions, and seek to protect U.S. intellectual property.

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### RECOMMENDATION

In light of the new competitive realities, the new NCIC should work with relevant federal departments and agencies—including Office of Science and Technology Policy, National Science Foundation, the intelligence community, and the Departments of State, Commerce, Energy, Treasury, and Justice—inviting advice from business and the academic sector, and national laboratories to develop guidance on U.S. participation in international relationships in science and technology (including global R&D collaborations and consortia), with the goals of maximizing the benefits to the United States, protecting U.S. taxpayer investment in research and development, and minimizing the risks to and maximizing U.S. science and technology leadership and U.S. national and economic security.

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### RECOMMENDATION

The NCIC should establish a federal policy and program to expand the U.S. role in international science, technology, and innovation initiatives that align with our national interests and prioritize U.S. participation to maximize advancement of U.S. goals.

56 State of U.S. Science and Engineering 2020, National Science Foundation, January 2020.

10x

## A NEW INNOVATION AGE CALLS FOR A NEW INNOVATION GAME

# 10x: Increasing the Number of Innovations Developed in and Deployed by the United States

## Increasing Investment in U.S. Research and Development

### Federal Support for U.S. Research and Development

The federal government has played a critical role in building U.S. strength in science and technology through funding of its mission-related research and development in areas such as health, defense, energy, and agriculture; its support of basic research at universities; and in building key science and technology infrastructure such as scientific user facilities and supercomputing resources. It has provided funds to advance technologies being developed by small businesses and supported efforts to advance the development and deployment of advanced manufacturing in U.S. industry. As private firms have increasingly focused their efforts on later stage research and product development to support their businesses, the federal government is increasingly called on to mature emerging technologies to increase their readiness for commercial applications. This is often referred to as investment to move technologies through the “valley of death.”

While the U.S. economy has continued to grow and become more technology-intensive, federal investment in R&D as a percent of GDP has been on a steady decline for more than 50 years, from a 1964 high of 1.86 percent of GDP—during a period of great challenge, and U.S. scientific and technolog-

ical ambition—to 0.62 percent of GDP in 2018.<sup>57</sup> If today’s federal R&D investment as a percent of GDP matched this 1964 height, the investment would be nearly \$400 billion, but was estimated to be around \$140 billion in 2019.<sup>58</sup>

Today, the United States faces threats, challenges, and opportunities equal to or greater than those experienced at the 1964 height of federal R&D investment as a percent of its GDP—even greater than those experienced during the early 1980s, as the Nation confronted the competitive challenges coming out of Japan and West Germany with a slight uptick in its federal R&D investment intensity. A rapidly strengthening strategic competitor aims to overtake U.S. global technological superiority, a threat to U.S. national and economic security. The world is confronted with grand challenges in health, adequate food, clean water, resource consumption, and sustainable energy that, left unaddressed, could cause severe environmental degradation and undermine geopolitical stability.

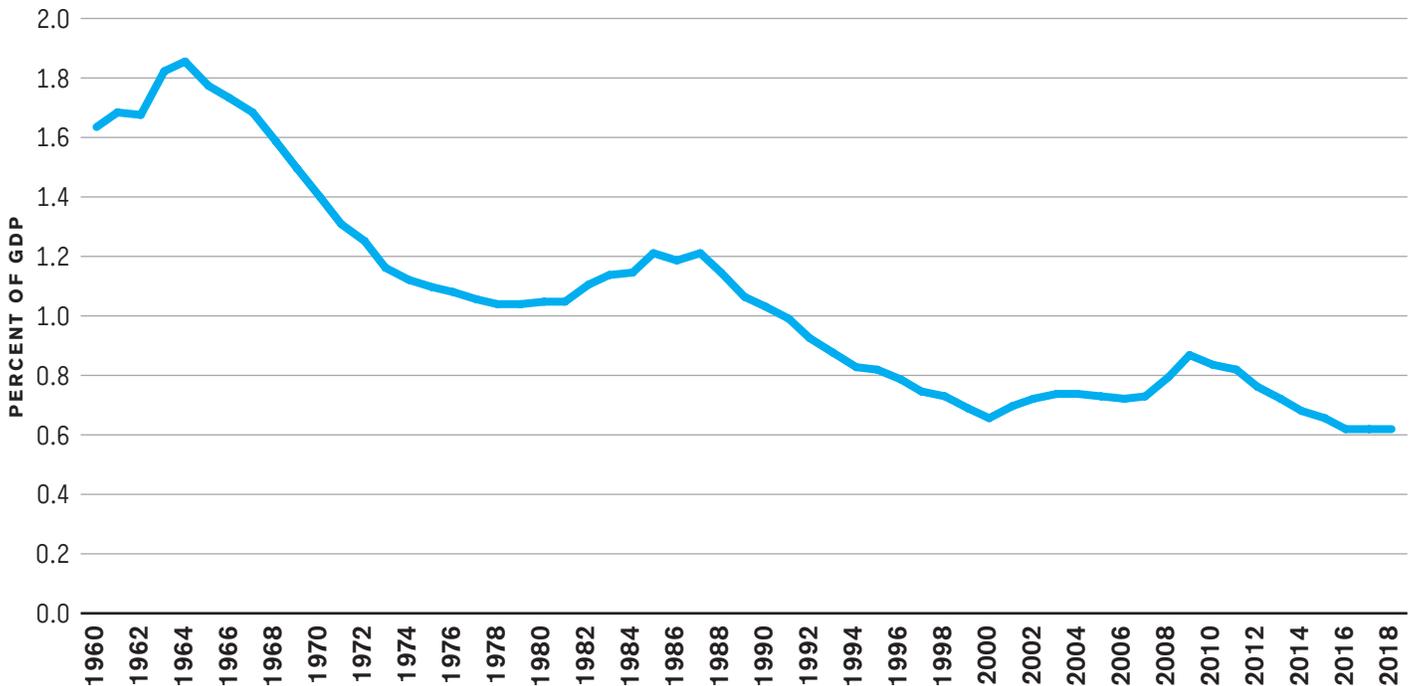
But solving these global problems also represents a golden opportunity for U.S. innovation and innovators. Multiple game-changing technology revolutions hold significant opportunities for U.S. innovators and industry to capture new product and service markets,

57 Table 1., National Patterns of R&D Resources Data Update, National Center for Science and Engineering Statistics, National Science Foundation, January 8, 2020.

58 Chapter 17. Research and Development, Analytical Perspectives, Presidents FY 2021 Budget, Office of Management and Budget, February 2020.

**Figure 9. Federal Government R&D Investment as Percent of GDP**

Source: National Science Foundation



drive economic growth, and create new American jobs and wealth—and there are certain technological domains, with tremendous impact on national and economic security, in which only a few nations have the capability to address.

Against this backdrop of conditions, substantial increases in federal R&D are needed to secure the U.S. technological advantage over rising competitors and position the United States for the opportunity to capture new, growing, technology-driven markets around the world. The additional investment should focus on applied research and pre-competitive development to advance emerging technologies to readiness for industry application and private sector commercialization.

## RECOMMENDATION

Congress should authorize and appropriate federal R&D investment levels, as a percent of GDP, to the levels of the mid-1960s (between 1.6 and 2.0 percent of GDP). The additional funds should be used for investment in applied research and pre-compet-

itive technology development in new kinds of institutions and models of R&D that engage the private sector in partnership, for example:

- Support investment and programmatic efforts to bridge the valley of death, to ensure that promising technologies developed by U.S. start-ups and small businesses are commercialized and scaled in the United States
- Develop and operate platforms where start-ups and small businesses can test and demonstrate their nascent technologies to generate the cost and performance data needed to attract private investment
- Increase private sector firms' and academic institutions' engagement with federal laboratories to advance applications of emerging technologies
- Fund new models of institutions focused on pre-competitive development and application of emerging technologies in U.S. industrial and services sectors of the United States

There are opportunities for greater leveraging of the federal R&D investment through multi-federal department and agency collaboration. For example, in connection with their missions, the Departments of Energy, Transportation, Defense, and Agriculture and NASA all have interests in autonomous, energy efficient vehicles, and many federal departments and agencies have an interest in artificial intelligence.

### RECOMMENDATION

Congress should provide federal departments and agencies the authority to contribute funds for research and technology initiatives supported jointly by multiple federal government entities.

Collectively, federal departments and agencies maintain a vast enterprise of laboratories, test facilities, scientific and research equipment, and science and engineering personnel. The capabilities at one federal department or agency could be used to advance the mission of another.

### RECOMMENDATION

Congress should provide federal departments and agencies the authority to fund research and technology development at the laboratories of other federal departments and agencies.

### Increasing Research and Development Investment by Start-up Businesses

The federal Research and Development tax credit currently allows businesses with up to \$5 million in gross receipts to apply the credit against their payroll tax obligation for five years. The proposed FORWARD Act (S.3593/HR.6713) would allow firms with up to \$20 million in gross receipts to use the credit to reduce their payroll tax obligation during a span of 8 years. The bill would also raise the payroll credit cap from \$250,000 to \$1,000,000 per year. Enacting this provision would create greater incentives for small businesses to invest in R&D.

### RECOMMENDATION

Congress should pass legislation to enact these provisions currently detailed in the FORWARD ACT.

### Leveraging the U.S. National Laboratory System to Support U.S. Innovation and Competitiveness

The federal government supports a vast constellation of research, development, and testing laboratories. Many of these are owned and operated by the federal government, while others are government-owned and company operated facilities in which the federal government has both funding and program relationships. These span a wide range of science and technology capabilities, including basic physical science, health care, military systems, transportation, space exploration, agriculture, industrial standards, energy, the environment, and more.

Prominent among these are the 17 crown-jewel National Laboratories of the U.S. Department of Energy, considered a distinctive U.S. competitive asset. These laboratories, including 28 user facilities, possess unique instruments and research facilities. Used by tens of thousands of researchers, these include advanced supercomputers, particle accelerators, large x-ray light sources, neutron scattering sources, specialized facilities for nanoscience and genomics, and others. They address large scale, complex research and development challenges with a multidisciplinary approach that places an emphasis on translating basic science to innovation. These facilities have a replacement plant value of more than \$130 billion.<sup>59</sup>

While these national laboratories focus on advancing their government missions, they also transfer technologies they develop to the private sector through patenting and licensing, and they partner with companies in areas of mutual interest under cooperative research and development agreements. However, where these laboratories have had their biggest

59 Annual Infrastructure Executive Committee Report to the Laboratory Operations Board, U.S. Department of Energy, March 27, 2018.

impact is where their capability has been brought to bear in a broader, more multidisciplinary effort. For example:

- The long-term collaboration with the semiconductor industry consortium SEMATECH advanced extreme ultraviolet lithography (EUV) for microchip fabrication. EUV promises to bring game-changing benefits in microchip fabrication, making it possible to make chips at smaller scale that are cheaper, more powerful, faster, and with lower power consumption—characteristics desired for chips used in 5G, Internet of Things, and artificial intelligence.
- Work at the national laboratories helped advance the horizontal drilling, hydraulic fracturing, and micro-seismic monitoring technologies that launched a shale oil and gas boom that helped turn the United States into the world's biggest producer of oil and gas, and to a net energy exporter for the first time since 1952.

These successes and others were enabled by:

- Sustained funding to the laboratories dedicated to a technology area that enabled laboratory staff to learn the area, and then bring to bear the laboratory's capabilities in facilities, scientific knowledge, computational toolsets, etc.
- Close, deep, and early involvement by industry to both guide and assimilate the joint technology development.
- Engagements with industry that did not involve "picking winners and losers."
- A willingness to accept risk as efforts must necessarily "look over the horizon."
- Recognition that the work must be concurrently connected to fundamental science but also strongly focused on applications at scale.

Today, the national laboratories have efforts that fit this model. However, they are not linked to an overall national strategy on innovation and competitiveness. To unleash fully the ability of the national laboratories to support a national competitiveness agenda, these characteristics must be present and aligned with

the goals of a national competitiveness and innovation strategy. Many U.S. competitors are working to implement similar arrangements within their own science and technology systems.

In addition, standardizing and streamlining contacting mechanisms required for national laboratory-private sector collaboration will lead to transferring knowledge and technology to the private sector more quickly.

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## RECOMMENDATION

While recognizing that the laboratory system must continue to be mission-driven, the United States should take steps necessary to enhance the contribution the Department of Energy's national laboratories can make to advancing U.S. innovation and competitiveness by adding and integrating this role into their mission:

- Congress and its relevant Congressional Committees should augment the U.S. Department of Energy mission responsibility, and authorize and appropriate resources to its national laboratories to support an overall national competitiveness and innovation agenda.
- Congress should require that the Department of Energy establish an office and management structure accountable for the effective use of its national laboratories to engage with and support the partnerships necessary to execute the national competitiveness and innovation agenda.
- Congress should require the Department of Energy and national laboratory leadership to set aside a portion of federal funding at the laboratories sufficient to apply their capability through effective partnership with industry and academia to national competitiveness challenges, and further deepening their expertise to advance the industrial adoption of key disruptive technologies. This includes efforts both within the laboratories, and with organizations around the United States that provide technology transfer and entrepreneurship assistance, and accelerator programs.

- Congress should provide the national laboratories with the appropriate flexibility to participate in and further invigorate collaborative laboratory, industry, and academic engagements that accelerate technology adoption and innovation.
- Permanently adopt the U.S. Department of Energy's Agreements for Commercializing Technology pilot, which establishes a lower barrier for contracts with businesses seeking to develop national laboratory research into new products and services.
- The Department of Energy should standardize and streamline contracting mechanisms required for national laboratory-private sector collaboration. This could include non-negotiable Cooperative Research and Development Agreements (CRADA) agreements with fair and reasonable terms, while allowing companies providing funding to negotiate more advantageous terms.

Future U.S. competitiveness will depend on the success of U.S. innovators developing, scaling, and deploying new product and process technologies. However, for those products and processes to reach and compete in high technology markets, additional research and development is often needed to scale concepts from benchtop implementations to full scale production. Providing support, both facilities and personnel, from the national laboratories to validate, scale, and advance new technologies with industry partners will help accelerate innovation in the United States.

Similarly, partnerships between universities, the nation's array of manufacturing institutes, and national laboratories offers the ability to advance the Technology Readiness Levels (TRL) of and de-risk a wide variety of technologies at an accelerated pace, increasing their readiness for private sector application, development, and commercialization, and accelerating their time-to-market in a world of hyper global competition.

As an additional benefit, such opportunities afford national laboratory personnel the chance to understand better the needs of industry and apply what they learn to their operations to better serve the needs of the Nation.

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## RECOMMENDATION

To leverage better unique-in-the-world and highly valuable U.S. science and technology assets and gain additional returns on the public investment in them, Congress should establish a fixed set of funds, renewable on an annual basis, that allows industry, universities, and the Manufacturing USA institutes to support focused research and development at the national laboratories. These funds would be awarded on a competitive basis and could be used over a multi-year period.

- Ensure that intellectual property arrangements are attractive to participating entities, and that other contractual issues are resolved rapidly before funding and projects commence.
- The federal government could give priority to projects that align to national goals and national critical technology needs.

## Infrastructure to Support the Next Economy

Capital, knowledge, ideas, skills, products, and services make our modern world go round, and they travel on infrastructure. In addition, countries that can mobilize a modern capital, knowledge, ideas, and skills infrastructure with the greatest speed, agility, and efficiency to build products and services have a competitive edge.

### A Digital Nation

Digital infrastructure is now the foundational platform for all U.S. infrastructure, the economy, and society—for all citizens; for government; for all industries, whether in manufacturing, agriculture, retail, entertainment, energy production and distribution, vehicles and transportation systems, communications, health care, knowledge and information acquisition; for every research enterprise; and more.

And this digital infrastructure's importance and pervasiveness will only grow as we deploy and scale smart rural, smart suburb and smart city technologies, intelligent highways, connected and driverless vehicles, smart grids, telehealth, personalized mobility

and medicine, virtual education, autonomous systems such as robots, and other “smart” systems. Vast deployment of big data, data analytics, and artificial intelligence in this infrastructure will drive productivity, and transformative economic and societal progress.

Into the future, our digital nation will offer tremendous opportunities for innovation, new markets and jobs, but it will also require research and new technology, the development of standards and regulations, and strong and widespread cybersecurity. Other nations are advancing their own digital infrastructures across society. For example, South Korea, Singapore, and cities such as London, Dubai, and Barcelona are already making investments and deploying technologies to develop smart cities. Smart cities involve key domains such as smart economy, environment, governance, living, mobility, and people.<sup>60</sup> They are living laboratories for innovation—and the basis for even more experimentation as suburbs and rural areas follow this trajectory.

To engage fully and productively in the economy and society, every American must have access to the public facing digital infrastructure, and the knowledge and skills needed to leverage it for personal growth and empowerment, economic gain, and a higher quality of life. Unfortunately, too many Americans do not have adequate access to this infrastructure or the skills to use it. Also, many communities, for example, low income urban and rural areas, do not have the digital infrastructure that could drive economic development.

## RECOMMENDATION

Similar to the vision the Clinton Administration issued in 1993 to guide development of the U.S. Information Infrastructure—*The National Information Infrastructure: Agenda for Action*—the NCIC should develop and issue a vision and set forth principles to guide the development and deployment of the next transformative stage of the U.S. Digital Nation across all relevant domains as described above. This new Agenda for Action should address key issues

such technology development, tax and regulatory policy, safety and cyber security, intellectual property, privacy, encouraging private and public sector investment, and other keys to rapid development and deployment. Of crucial importance are policies and programs that enable all Americans to access this foundational advanced digital infrastructure, and to ensure all Americans have the needed digital skills to leverage it for a wide range of economic and personal benefits.

## Closing the Digital Divide

American society is now fundamentally integrated into a digitalized world of work, commerce, education and training, healthcare, public and commercial services, utilities, news and entertainment, information research, and other human activities. These necessities of life are accessible through Internet services provided over broadband networks.

Accessing the Internet and its broadband networks, employees telework from home or any location, students access education, and workers train to upgrade their skills. Customers access banking and financial services from their home computers or cell phones, and purchase many of the items they need for life for home delivery after using the Internet to find the best price. Job seekers search job listings in employment data bases, while an increasing number of patients see their physicians through a telehealth appointment. Communications with family, friends, employers, and service providers travel routinely over broadband networks. Simply put, fully participating in American society is now dependent on an individual's access to the Internet and broadband networks.

Broadband is also an essential 21st century infrastructure for economic development and vitality. Communities with robust broadband have a distinct advantage in attracting business capital investment to support innovators and new business formation, economic and industry growth, and job creation. Individuals with digital literacy skills are better able to find employment, are more productive in many jobs, and more able to increase their incomes.

Numerous studies have found a positive economic impact of broadband deployment, for example, in terms of business formation, job creation and median income growth.<sup>61</sup>

Based on the current federal Communications Commission's speed benchmark of 25/3 Mbps (download/upload speed) for fixed terrestrial service "advanced telecommunications capability," as of year-end 2018, 94.4 percent of the overall population had coverage of such services. Many areas have faster service, for example, fixed terrestrial service of 50/5 Mbps service is deployed to 92.7 percent of the population, 100/10 Mbps to 90.5 percent of the population, and 250/25 Mbps to 85.6 percent of the population.<sup>62</sup>

In general, the greater the download and upload speeds offered by a broadband connection, the more sophisticated (and potentially valuable) the application that is enabled. When a high-demand application—such as streaming HD-video, multiparty video conferencing, and telecommuting—is running by two or three household users at the same time, more advanced broadband service may be needed.<sup>63</sup> This is the kind of scenario that has occurred during the COVID-19 pandemic, for example, a parent telecommuting from home, while two students participate in live on-line classes.

61 Measuring Broadband's Economic Impact, report prepared for the Economic Development Administration, U.S. Department of Commerce, February 28, 2006, [http://cfp.mit.edu/publications/CFP\\_Papers/Measuring\\_bb\\_econ\\_impact-final.pdf](http://cfp.mit.edu/publications/CFP_Papers/Measuring_bb_econ_impact-final.pdf); The Effects of Broadband Deployment on Output and Employment: A Cross-sectional Analysis of U.S. Data, June 2007, <https://www.brookings.edu/research/the-effects-of-broadband-deployment-on-output-and-employment-a-cross-sectional-analysis-of-u-s-data>; The Substantial Consumer Benefits of Broadband Connectivity for U.S. Households, Internet Innovation Alliance, July 2009, [http://internetinnovation.org/files/special-reports/CONSUMER\\_BENEFITS\\_OF\\_BROADBAND.pdf](http://internetinnovation.org/files/special-reports/CONSUMER_BENEFITS_OF_BROADBAND.pdf); The Digital Road to Recovery: A Stimulus Plan to Create Jobs, Boost Productivity and Revitalize America, Information Technology and Innovation Foundation January 2009, <https://www.itif.org/files/roadtorecovery.pdf>; Broadband's Contribution to Economic Health in Rural Areas, Research & Policy Brief Series, Community and Regional Development Institute, Cornell University, February 2015, available at <https://cardi.cals.cornell.edu/sites/cals.cornell.edu/files/shared/documents/Research-PolicyBriefs/Policy-Brief-Feb15-draft03.pdf>; The Economic Impact of Rural Broadband, Hudson Institute, April 2016.

62 2020 Broadband Deployment Report, Federal Communications Commission, April 24, 2020.

63 Household Broadband Guide, Federal Communications Commission.

Unfortunately, many residents living in remote rural communities, on tribal lands, and low income neighborhoods, or who have a disability, are unconnected or under-connected, for example, have only a smart phone to connect to the Internet. The gap in rural and Tribal America remains notable: 22.3 percent of Americans in rural areas and 27.7 percent of Americans in Tribal lands lack coverage from fixed terrestrial 25/3 Mbps broadband, as compared to only 1.5 percent of Americans in urban areas. According to the FCC, approximately 21.3 million Americans lack a broadband connection speed of at least 25/3 Mbps, the current FCC benchmark.

In contrast to broadband availability, which refers to whether or not broadband service is offered, broadband adoption refers to the extent to which American households actually subscribe to and use broadband. Thirteen percent of households in the United States do not have a broadband Internet subscription; in some states 20 percent of households do not.<sup>64</sup>

The most recent survey data from the Pew Research Center show that populations continuing to lag behind in Internet adoption include people with low incomes, seniors, the less-educated, and households in rural areas. Twenty-seven percent of those 65 and older do not use the Internet, 29 percent of those without a high school diploma, and 15 percent of those living in rural areas. Eighteen percent of those earning \$30,000 or less do not use the Internet, compared to just two percent who earn \$75,000 or more.<sup>65</sup> Affordability, lack of perceived relevance, and lack of computer skills are the principal barriers to broadband adoption.<sup>66</sup>

People stuck on the wrong side of this Digital Divide—or staring over the edge of a Digital Cliff—are being left behind at an accelerating pace, struggling

64 2019 American Community Survey Data Wheel.

65 10 Percent of Americans Don't Use the Internet. Who Are They?" Fact Tank, Pew Research Center, April 22, 2019.

66 Government Accountability Office, Intended Outcomes and Effectiveness of Efforts to Address Adoption Barriers Are Unclear, GAO-15-473, June 2, 2015, p. 11, available at <http://www.gao.gov/assets/680/670588.pdf>.

or unable to apply for a job, access public services, obtain public safety information during an emergency, and are increasing disenfranchised from participation in the economy and many digitized activities of society and human life. The COVID-19 pandemic magnified this Divide as stay-at-home orders forced millions of people to try to be online simultaneously, exposing the inadequacies of home Internet services and spotlighted the need for much higher delivered speeds and more synchronous networks that will allow, for example, both parties in a tele-meeting to see, talk, and listen simultaneously, or to have an on-line chat with a physician.

Closing the Digital Divide requires strategies and investments to address the challenges of both deployment and adoption to increase the use of technologies enabled by ubiquitous high-speed Internet infrastructure. Internet Service Providers (ISPs) have invested billions of dollars in building and upgrading their networks to provide increasingly better broadband networks that can deliver higher speeds and better technologies. This nation embraces capitalism to serve the consumer interest and should continue to do so with a commitment to transparent competition and a level playing field to operate in the public interest.

However, ISPs cannot be expected to deploy Internet infrastructure where a profit is not possible. The marketplace is not operating to reach the most remote rural communities, including Tribal Lands, or to upgrade networks in the poorest urban neighborhoods. Achieving ubiquitous high-speed Internet access throughout the Nation will require taxpayer and ratepayer subsidies to build adequate infrastructure to reach all unconnected and under-connected areas.

Closing the Digital Divide with public policies and strategies to achieve ubiquitous broadband deployment and to accelerate broadband adoption is an imperative for economic prosperity, quality of life, and family self-sufficiency. Fortunately, it is a goal that can be achieved with inspired vision, focused leadership, measurable goals, alignment of exist-

ing resources, and investment of public funding to encourage partnerships—federal-state, public-private, and provider-community.

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## RECOMMENDATION

The federal government should launch a U.S. Digital Infrastructure Access and Inclusion Initiative.

- Set national goals and performance metrics with a timetable for broadband deployment, including capacity and speed, and for adoption, including affordability and digital literacy.
- Authorize a federal investment on the order of \$100 billion for both broadband deployment and adoption, including digital skills development, and incorporate Digital Inclusion into all federal programs and services related to broadband deployment and adoption.
- Reform the regulatory environment to embrace performance-based regulations that promote public-private partnerships to create incentives for and reward private-sector investment.
- Leverage federal investments by matching state and local funding and initiatives.
- Establish a robust Internet Lifeline Program to augment improved ISP affordable offers.

## Infrastructure for the 21 Century Knowledge and Innovation Economy

Much like roads, rail, water infrastructure, and power plants were essential for the Industrial Age, infrastructure that supports knowledge creation and technology development is vital for the 21st century innovation economy and U.S. success in innovation-based global competition. This infrastructure includes—but is not limited to—laboratories, research and technology demonstration centers, supercomputers, test-beds, wind tunnels, propulsion and combustion facilities, simulators, accelerators and other user facilities.

Innovators and innovating companies of all sizes may need specialized infrastructure to test, demonstrate, or otherwise advance their new technologies and innovations, yet do not have ready or cost-ef-

fective access to the needed infrastructure. In many cities throughout the country, there is a lack of sufficient laboratory space to investigate new drugs, robotics, and other innovations. Also, as new technology emerges—such as artificial intelligence and autonomous systems—new infrastructure for testing, demonstration, validation, even certification is needed. Moreover, building a base of knowledge, sharing ideas, and building innovation capacity can be facilitated by geographic agglomeration, for example in hubs and research parks, or where new firms and their ideas can be nurtured in incubators and advanced in accelerators.

### RECOMMENDATION

Federal and state governments, and regional partnerships should invest in the infrastructure needed to grow a 21st century economy, such as the development of medical and scientific research parks, laboratories, and incubators, and ensure they are supported by advanced digital infrastructure and platforms.

- Federal infrastructure spending plans should be revised to include a three percent set-aside for technology parks, labs, incubators, and other research-related infrastructure.

U.S. national laboratories and their often state-of-the-art facilities and equipment are a competitive advantage for the United States. However, across the system, core scientific and technological capabilities are potentially at risk due to deficient and degrading infrastructure. Space in many facilities within the system is old, outdated, even obsolete, with maintenance backlogs in the hundreds of millions of dollars. While this national treasure deteriorates, China is investing heavily in national and state “key” laboratories, and many other research and engineering centers focused on science and emerging technologies. In contrast, in the United States, maintenance and repair in the national laboratory system is hamstrung by chronic underfunding.

### RECOMMENDATION

Grow and refresh core national laboratory infrastructure.

- Congress should appropriate funds adequate to modernize the facilities and key equipment at U.S. national laboratories.
- Develop an inter-agency initiative to develop a plan for greater connections between and collaboration among the federal laboratories, and more rational investment in and management of research when the departments or agencies have common needs and goals.

### Opening Access to Innovation-Supporting Infrastructure

“Hard-tech” companies often need access to expensive, specialized research capabilities that often are too expensive for a single company to acquire, staff, and maintain. To achieve a leadership position in the industries of the future—such as advanced manufacturing, quantum information science, and biotechnology—academic and industry researchers must have access to world-class scientific facilities and capabilities staffed by experts.

In addition, many innovation-driven enterprises need access to major research equipment to complete their R&D and prototyping, and these enterprises account for a significant proportion of innovations that drive economic development and competitiveness in the United States. Yet, access to federally-funded research equipment through fee-for-service agreements can be cost-prohibitive, especially for small businesses and early stage enterprises, who are then unable to complete R&D or prototyping for their technology or company. If these innovators could get access to these facilities and equipment to move their technologies along the pathway to the marketplace, larger numbers of innovations could be developed and commercialized in the United States, particularly by entrepreneurs without access to substantial financial resources, including underrepresented minority groups, women, and recent university graduates.

## RECOMMENDATION

The federal government should take steps to expand access to the Nation's network of shared research resources and equipment for high-risk, early stage innovation-driven enterprises. Create a federal policy or funding pool to offset the costs of accessing federally-funded research equipment for non-lab affiliated entrepreneurs working on research and development for early stage companies.

- Create policies that allow hosts of federally-funded research equipment to offer low cost or no cost access to non-affiliated companies based on financial need, and/or create funding streams to offset fees for companies to access equipment for R&D and prototyping for early stage enterprises.
- Federal departments and agencies should simplify contracting mechanisms required to access these research and development resources. This includes streamlining approval processes for access these resources and adopting common partnering agreements across the Department of Energy, and other federal user facilities.
- Invest in programs to raise awareness of these facilities, particularly to early stage companies, and provide resources to assist companies in access these resources.

## Establishing a New Model for Developing and Deploying Emerging Technologies at Scale

Throughout the 20th century, some U.S. corporations operated large, free-standing centralized industrial research laboratories that developed inventions and applications in response to real world problems, possibilities, and user needs. These laboratories housed specialized equipment and facilities to test and validate inventions and applications, and they were institutionally connected to integrated production facilities, simplifying the flow of new applications to production with no technology transfer gap or valley of death.

Corporations have refocused their technical efforts largely to product development. With few exceptions, the United States no longer has large, multidisciplinary-staffed industrial labs connecting broad areas of research and technology to problems and market possibilities. This has left the United States with a weaker capability to translate new technology developments into applications and economic impact.

One exception is the large multidisciplinary laboratories run by some federal agencies, such as those at the Departments of Energy and Defense. However, while similar in scale, scope, and capabilities of old industrial research laboratories, these laboratories are focused on achieving their government missions. Another exception are several large high-tech hubs on the coasts of the United States, which are world leaders in scaling applications in the digital and biotechnological domains. These hubs are anchored by large companies and/or top research universities or institutions. They are also start-up generators, but start-ups do not have the resources to bring their technologies to scale.

Now, with few exceptions, the U.S. innovation ecosystem is mostly broadly divided into two large research and innovation sectors:

- Academic research at universities, largely agglomerations of single-discipline, investigator-driven, small scale basic and exploratory research focused on discovery and knowledge generation
- Product development in private companies

This division of labor has created a “missing middle” in applications research, where invention occurs and innovation begins. It has also resulted in a time-consuming technology transfer gap (when new discoveries or technologies are “transferred” to the private sector), and the valley of death (in which immature technologies emerge from universities or start-ups but they do not have the resources to de-risk them to make them more attractive for private sector investment and commercialization). In addition, most STEM students are trained to work in an academic research setting even though most will work in the private sector.

To fill this missing middle—in attempts to stimulate the transfer of university research to the private sector for commercialization, and close the valley of death—the United States has established numerous research initiatives, institutes, etc. However, they can be:

- Diffuse, fragmented, and distributed
- Relatively small in scale
- Limited in their disciplinary domain
- Often disconnected from specialized equipment for testing and verification
- With few exceptions, such as the 15 Manufacturing USA institutes, they operate at arms-length from industrial production, the marketplace, and real world problems

A new model of R&D organization that focuses and helps integrate the efforts of all parts of the innovation enterprise could help fill that missing middle. These entities—which could be institutes, consortia, smaller research and application centers, or hubs—should be distinct from, but compliment the efforts at national laboratories, basic research at universities, and other institutes and initiatives. Characteristics should include:

- Industry-driven, with partnerships that engage universities, national laboratories, and government.
- Portfolio of real-world problem- or possibility-driven collaborative R&D (with a focus on applications); feeding back areas of needed inquiry to basic research
- Multi-disciplinary staffing
- Shared equipment and facilities for prototyping, test, and verification
- Industrial partners that can support translation of inventions and innovations by connecting to production capabilities in an integrated development cycle
- Culture and focus on problem-solving, inventing, and making things (as opposed to academic research or product development)
- Flexible IP frameworks that encourage industry participation and incentivize commercialization

- Training for STEM workers that is similar to R&D work in the private sector
- Funding and staffing at scale (X100 to X1,000), depending on the scope and scale of the research and technology opportunity
- Supporting ecosystem—patient capital, legal, regulatory, policy, entrepreneurial development, and economic development—to speed applications to the marketplace and fully leverage the research activity for economic impact in the surrounding region.

There are many possibilities for the research and technology agenda of organizations designed on this new model. For example, they could focus on:

- Foundational technology with numerous application domains such as artificial intelligence, biotechnology, or autonomous systems
- Broad sectors where numerous disruptive technologies are converging such as health and personal mobility
- Grand problems or needs that numerous technologies have the potential to address, such as green chemistry, clean water, clean energy, or infrastructure modernization
- Large social needs such as materials for a circular economy, or sustainable cities where numerous technologies could be applied
- Emerging opportunities such as smart cities or the industrialization of space

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## RECOMMENDATION

With funds from an expanded public investment in R&D, the federal government should co-fund with industry several pilot at-scale initiatives to demonstrate new models of application-oriented R&D efforts with the above mentioned characteristics. These should be selected based on a rigorous competition taking into account industry commitment, technical capability and capacity, opportunity landscape and potential for economic impact, and adequacy of supporting ecosystem elements.

## Spurring Innovations for More Sustainable Production and Consumption

With increasing industrial and economic development, and rising incomes around the world, consumption of energy and material resources is on an upward trajectory. For the first time since agriculture-based civilization began 10 millennia ago, the majority of the world's population—just over half—could be considered middle class or richer.<sup>67</sup> By 2030, the global middle class could reach 5.3 billion—1.7 billion more than today. These new middle class consumers will want a wide range of products and services.

For example, according to the UN, the per capita “material footprint” of developing countries increased from five metric tons in 2000 to nine metric tons in 2017. In high income countries, the per capita material footprint is 27 metric tons. Today, many products are designed for single use only, break down too quickly, and cannot be easily recycled. Globally, 37 percent of waste is disposed in a landfill.<sup>68</sup> In the United States, in 1960, the generation of municipal solid waste was just 2.68 pounds per person per day but has increased to 4.9 pounds per person per day in 2018. Half of this waste ended up in landfills.<sup>69</sup> The extraction and processing of materials, fuels, and food contribute half of total global greenhouse gas emissions and more than 90 percent of biodiversity loss and water stress.<sup>70</sup>

Global consumption of materials such as biomass, fossil fuels, metals, and minerals is projected to double in the next 40 years,<sup>71</sup> and annual waste

generation to increase by 70 percent by 2050.<sup>72</sup> As demand for energy and material goods is rising, pressure to make production and consumption more sustainable is growing as resource depletion, environmental degradation, and pollution is projected to have significant negative effects on natural habitats, health and, potentially, species and human survival. Future competitiveness will be dependent on those who can create high value products in all sectors that will function within the resource limitations of our planet.

Advances in technology could increase the sustainability of production and consumption. Platform technologies are needed in many sectors—such as green chemistries, alternatives to plastics, and green materials—where existing companies have little incentive to invest, they are inputs to their primary product markets, and start-ups have barriers to market entry.

For example, current recycling methods often do not allow for profitable recycling of commonly used plastics. As a result, only 14 percent of the 78 million tons of plastic packaging produced each year are collected for recycling. Developing new materials with functional barrier properties and mechanical performance that match or exceeding incumbent plastic materials is a major R&D challenge.<sup>73</sup>

Increasing recognition of the resource constraints of the planet means that environmentally responsible inventions and associated products will be in increasing demand. Such inventions include new chemistries, materials, devices, processes, or other inventions across the full range of sectors. However, currently, the market or other incentives for developing sustainable inventions are weak.

67 A Global Tipping Point: Half the World is Now Middle Class or Wealthier, Homi Kharas and Kristofer Hamel, Brookings, September 27, 2018.

68 What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050, World Bank, 2018.

69 Advancing Sustainable Materials Management: 2018 Fact Sheet, Assessing Trends in Materials Generation and Management in the United States, U.S. Environmental Protection Agency, November 2020.

70 UN Environmental Program, <https://www.unenvironment.org/news-and-stories/press-release/un-calls-urgent-rethink-resource-use-sky-rockets>.

71 Global Material Resources Outlook to 2060, OECD.

72 What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050, World Bank, 2018.

73 Plastics for a Circular Economy Workshop: Summary Report, U.S. Department of Energy, July 2020.

## Global Cooling Prize

The number of room air-conditioning units globally is expected to increase from about 1.2 billion units today to 4.5 billion units by 2050 as a result of increasing climate temperatures. A dramatic increase in comfort cooling could perpetuate climate warming.

A global coalition—the Rocky Mountain Institute, the Department of Science and Technology of the Government of India, and Mission Innovation aided by Conservation X Labs, Alliance for an Energy Efficient Economy, and EPT University—launched the Global Cooling Challenge to spur development of a room air-conditioner with 5X less climate impact, while providing affordable access to cooling to billions of people around the world.

The winning solution must operate within pre-defined limitations on refrigerants, water, full-load power consumption, emissions, volumetric size, materials, and operational requirements. It will need to be affordable to typical consumers.

At least \$2 million in prize money will be awarded to support prototype development by Prize finalists. Prototypes will be tested for performance in the laboratory and real-world conditions in a heat-stressed city in India. The winner will be awarded at least \$1 million to support commercialization and scaling of the innovative technology. The coalition will help drive incubation, commercialization, and mass adoption, starting in India and expanding to countries such as China, Brazil, and Indonesia. To support scaling of the winning technology, the coalition is engaging policymakers, manufacturers, financiers, and major buyers to line up potential investors, advance standards, and secure advance market commitments.

## Leveraging the U.S. Patent System to Stimulate Sustainable Inventions

A critical step in the innovation pathway—from idea to product—is the capture of intellectual property (IP) that supports both public disclosure of the innovation to the world, while protecting the follow-on investment in developing the idea to yield benefit for the IP owner.

In another area of need where incentives are weak—innovation to meet global humanitarian challenges—the U.S. Patent and Trademark Office (USPTO) developed Patents for Humanity. This program provides businesses incentives to develop inventions for underserved markets. Winners receive an acceleration certificate to expedite select proceedings at the USPTO, and public recognition of their work. Examples of winning innovations include: a kit to provide prescription eyeglasses cost-effectively for people who normally do not have access to vision care, mechanical alternative to transfusing donor blood, portable solar light, waste processing plant that transforms human waste into sanitary briquettes that replace wood and charcoal for heating and cooking, and membrane bioreactor technology to create a machine capable of simultaneous recovery of nutrients, energy, and water from wastewater. A similar program could heighten awareness of inventions that address sustainability, and provide entrepreneurs, inventors, innovators, and businesses incentives to create inventions that will lead to more sustainable products.

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### RECOMMENDATION

The U.S. Patent and Trademark Office should launch the Patents for Our Planet program, providing winners both public recognition and accelerated proceedings at the USPTO. USPTO could considering granting winners a 1-2 year extension of IP coverage.

## Building the Eco-system for Sustainable Technologies

Many technologies that could help achieve sustainable supply and production for the future lack market incentives, are insufficiently de-risked for existing companies to invest in their development, and difficult for start-ups to tackle for reasons such as cost of infrastructure, prolonged time to market, capital intensity, or lack of access to market data and corporate partnerships.

In established markets, key players have the knowledge of markets and technological possibilities, so they are willing to support and nurture a start-up business. But, in nascent or novel markets, key players may not be clear or even lacking, and a baseline of knowledge and experience may not have been built in the investment community. Taking on the development of a new market—such as identifying the support, financing, regulatory strategy, and path to market—may be beyond the ability of a start-up focused on developing the novel technology. A coordinated and supported effort is needed to stitch together the pieces of the innovation pathway for priority sustainable technologies key to future competitiveness. The Global Cooling Prize is an example of an effort designed to bring together the necessary pieces of the innovation ecosystem to develop, commercialize, and scale a sustainability solution.

### RECOMMENDATION

Led by the NCIC—in consultation with the Departments of Commerce, Energy, Agriculture, Interior, and Transportation, the Environmental Protection Agency, and others—the federal government in partnership with industry should identify key technologies on which future sustainability is dependent—taking into account factors such as need, sustainability impact, and current market incentives and barriers. The

federal government should provide some support to catalyze the formation of Sustainability Innovation Consortia to tackle commercial development of these technologies.

- The NCIC should launch a public-private effort to identify the key technologies on which future sustainability is dependent and map the business opportunities associated with those technologies. A similar roadmap was developed in the Global Roadmap for Implementing CO<sub>2</sub> Utilization, which analyzed the state of CO<sub>2</sub> utilization technologies, and identified four major market opportunities in fuel, building materials, chemical intermediaries, and polymers.<sup>74</sup>
- A partnership of private entities (corporate and philanthropic), academia (transdisciplinary scholars), and the federal government should provide support to catalyze the formation of Sustainability Innovation Consortia of technical and policy experts, accelerators, innovators, start-ups, companies, philanthropic institutions, and investors to drive development and commercialization of the needed technologies. The Consortia would serve as a collaborative platform to integrate the efforts of startups, investors, and corporations, and involving experts with market, regulatory, and policy knowledge, working together to accelerate the development, commercialization, and scaling of sustainability innovations, solutions, and technologies—essentially creating an innovation ecosystem. Coaching startups in an accelerator program will increase their odds of attracting follow-on investment and forge strategic partnerships in sales, development, and manufacturing.
- In support of these consortia, and in coordination with the National Innovation and Competitiveness Council, building on its role in helping coordinate federal R&D investment, the White House Office of Science and Technology Policy could engage

<sup>74</sup> Global Roadmap for Implementing CO<sub>2</sub> Utilization, Lux Research for CO<sub>2</sub> Sciences, and University of Michigan Global CO<sub>2</sub> Initiative, 2019.

key federal departments and agencies to provide funding to advance the priority technologies, if additional incentives are needed, and coordinate development. The U.S. Department of Commerce's Economic Development Administration could provide catalyst funding to assemble the partnering entities needed to create an accelerated path through development to market, as well as the accelerators and incubators needed to cultivate the start-up companies.

### Policy Tool Kit

The federal government has policy tools it can use to incentivize private investment and development of sustainable technologies, particularly where existing market incentives do not advance the needed technology. For example, the federal government recognized the need for pharmaceutical companies to focus on therapies for rare diseases and conditions, although unlikely to create sufficient compensatory profits, which created a barrier to their development—even though these diseases and conditions affected 20-25 million patients who, together, suffered from some 5,000 rare diseases.<sup>75</sup> The Orphan Drug Act of 1983 provided financial incentives to attract industry's interest through a seven-year period of market exclusivity for a drug approved to treat an orphan disease, even if it were not under patent, and tax credits of up to 50 percent for R&D expenses. In addition, the Act authorized the Food and Drug Administration to designate drugs and biologics for orphan status, provide grants for clinical testing of orphan products, and offer assistance in how to frame protocols for investigations. The Act has driven significant growth in orphan drugs under development and those in the marketplace.

A similar law has the potential to incentivize R&D spending for technologies that meet sustainability and green objectives and position the United States for competitive advantage as the market and urgency for these technologies grows around the world.

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### RECOMMENDATION

Congress should institute incentives for private investment and development of sustainable technologies. Modeled after the Orphan Drug Act, this could include instituting a designation process for sustainable and green technologies and offering a range of incentives for developing technologies that receive such a designation. For example:

- Amend the Internal Revenue Tax Code to allow for a tax credit for R&D efforts under such designation.
- Authorize appropriations for grants and contracts within the National Science Foundation, the U.S. Departments of Energy and Agriculture, and other granting agencies for R&D efforts under such designation.
- Create a national loan program to support efforts under such designation.
- Create a program of grants to K-12 and higher education to support development and dissemination of curricula and materials that support efforts under such designation.
- Create compensatory patent extension programs that support efforts under such designation.

75 The Story Behind the Orphan Drug Act, U.S. Food and Drug Administration, 2018.

10x

**A NEW INNOVATION AGE CALLS FOR A NEW INNOVATION GAME**

# 10x: Increasing the Speed at Which the United States Innovates

## 10x Bridging the Valley of Death—From Start-up to Scale Up

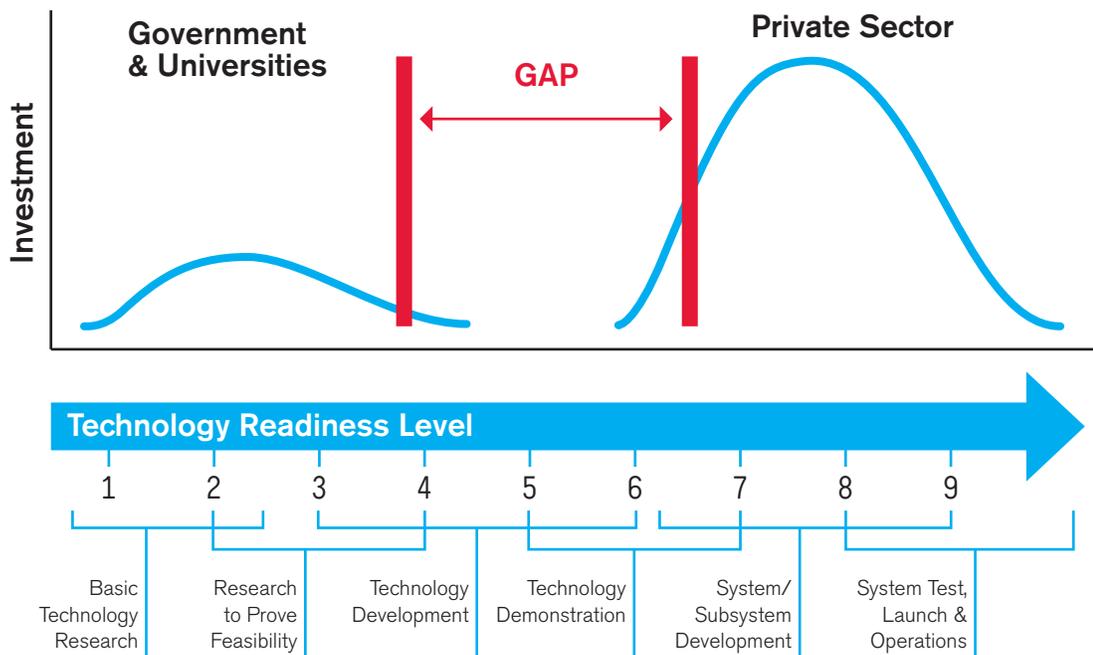
The so-called “valley of death” is a major and pervasive bottleneck in the U.S. innovation system, preventing many potentially valuable innovations from reaching the marketplace or slowing their progress toward commercialization, and keeping many start-ups from a pathway to growth. Trapped in the valley of death, these technologies and innovations, and the start-up companies striving to bring them to market

are vulnerable to foreign acquisition often at fire sale prices. Or their technologies are manufactured and their value chains created off-shore.

A first valley of death is reached when start-ups and other companies cannot obtain the capital needed to prototype, demonstrate, test and validate their innovations, lowering risk and generating the performance and cost data needed to attract commercial financing. This occurs when technologies and inno-

**Figure 10. Valley of Death-Gap in Innovation**

Source: Advanced Manufacturing Partnership Steering Committee Report, President’s Council of Advisors on Science and Technology.



**Figure 11. Valley of Death—TRL/MRL 4-7**

Source: Executive Office of the President, National Science and Technology Council.

TRL 1	Basic principles observed and reported	MRL 1	Basic manufacturing implications identified
TRL 2	Technology concept or application formulated	MRL 2	Manufacturing implications identified
TRL 3	Experimental and analytical critical function and characteristic proof of concept	MRL 3	Manufacturing proof of concept developed
TRL 4	Component or breadboard validation in a laboratory environment	MRL 4	Capability to produce the technology in a laboratory environment
TRL 5	Component or breadboard validation in a relevant environment	MRL 5	Capability to produce prototype components in a production relevant environment
TRL 6	System or subsystem model or prototype demonstrated in a relevant environment	MRL 6	Capability to produce a prototype system or subsystem in a production relevant environment
TRL 7	System prototype demonstration in an operational environment	MRL 7	Capability to produce systems, subsystems, or components in a production representative environment
TRL 8	Actual system completed and qualified through test and demonstration	MRL 8	Pilot line capability demonstrated; ready to begin low rate initial production
TRL 9	Actual system proven through successful mission operations	MRL 9	Low rate production demonstrated; capability in place to begin full rate production
		MRL 10	Full rate production demonstrated and lean production practices in place

vations arise in the start-up sector, and when they are transferred or “spin-out” from universities into the private sector for application and commercialization.

Often, the federal government, national laboratories, and universities support the scientific discovery, research and early technology development through “Technology Readiness Levels” or “Manufacturing Readiness Levels” (TRL/MRL) 1-3. Once de-risked, private sector investors (and the federal govern-

ment if government mission critical) may pick-up the ball and fund these innovations at TRL/MRL 8-10. Getting through the Valley of Death is traversing TRL 4-7. Angel and venture capital investors may step in with smaller amounts of support to advance the technology to a prototype ready for demonstration or testing for manufacturability, but venture capital is highly concentrated in software and life sciences.

One weakness in the U.S. innovation ecosystem that contributes to this first valley of death is a lack of testing infrastructure, sites, and test beds where innovators can test, demonstrate and validate their technologies.

Companies that move through this first valley of death may reach a second one—when the risk of the technology or innovation has been substantially reduced, but the cost to scale manufacturing has risen substantially. Scaling requires the establishment of supply chains, designing and establishing production processes, purchasing and installing tooling and other equipment, putting testing and quality controls in place, staffing, and may require building a new manufacturing facility.<sup>76</sup>

For example, a new manufacturing facility could require \$1 billion in upfront capital, financing requirements of a scale that cannot be met by government or venture capital. Funding of this magnitude requires debt financing, typically underwritten by large banks. If start-ups do make it through the first valley of death, they require substantial financial backing that may not be attractive for investors looking for a shorter- and higher return on investment. In some other countries, additional incentives are provided to encourage larger investments at this stage. Or, when the capital level required is large, the manufacturing of U.S. innovations frequently is scaled off-shore.

The challenges associated with bridging the valleys of death are greater with hardware technologies and can be even greater still with “new to the world” technologies, when a baseline of knowledge and experience has not been built in the investment community. For example, despite the need, venture capitalists and firms have so far shown little interest in climate change-mitigating technology, due to the scale and risk of the investments.

Bridging the valley of death is one of the highest priorities in raising the rate of U.S. innovation and U.S. scaling of new technologies. In attempts to bridge the gap, federal and state governments have

instituted a few initiatives. At the federal level, this includes supporting 14 Manufacturing USA institutes on different technologies, and some federal departments have extended Small Business Innovation Research program (SBIR) funding further into the development life-cycle. Some state governments have set-up modest funds to help start-ups at this stage of innovation.

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## RECOMMENDATION

Congress should establish a new research transformation capacity grant program to bolster regional strategies to convert research into new products and services throughout the country aimed at supporting U.S. start-ups and small businesses bridge the valley of death and scale their technologies:

- Federal departments and agencies with R&D budgets greater than \$100 million should set aside a percentage of their annual budgets (the Start-up Act last introduced in 2019 suggested a set aside of 0.15) to provide funding to organizations at the regional and local level to support proof-of-concept activities such as prototype development and testing, and other work, such as securing regulatory approvals, needed to demonstrate new technologies at a sufficient level to attract private investment.

### Small Business Innovation Crossing the Valley of Death.

Efforts to advance innovations by start-ups and small firms are supported by some government funding. But that funding can decrease abruptly after a technology is created, right when funds are needed to test and begin commercializing the technology.

For example, the federal Small Business Innovation program (SBIR) encourages small businesses to participate in federally-funded research and development with commercial potential. Eleven federal departments and agencies with research budgets greater than \$100 million per year must set aside 3.2 percent of their extramural research budget for

<sup>76</sup> Bringing Manufacturing Back to the U.S. is Easier Said Than Done, Willy C. Shih, Harvard Business Review, April 15, 2020.

SBIR grants, currently a total funding pool of about \$3.2 billion per year. SBIR makes more than 5,000 new awards every year, and companies such as 23andMe, Biogen, Symantec, and Qualcomm have been supported in their early years through the SBIR program.<sup>77</sup>

A three-phase merit-based program, SBIR enables small businesses to receive awards up to about \$260,000 to establish technical merit, feasibility, and commercial potential of their R&D or technology in Phase I, and up to \$1.7 million in Phase II to continue the R&D effort or develop a prototype.<sup>78</sup> In Phase III, small businesses are expected to pursue commercialization without SBIR funding, although some agencies can offer financial support beyond the first Phase II award.

## RECOMMENDATION

Congress should reauthorize the SBIR program, allowing agencies to offer merit-based Phase III grants to small businesses that have acquired a match funded by their State to advance their technologies over the valley of death and closer to commercialization. A substantial increase in the overall federal R&D budget, as recommended in this report, can fund the federal portion of this program expansion.

## Amplifying University Technology Transfer, Commercialization, and Industry Engagements

Universities play a critical role in the U.S. innovation system, performing the Nation's basic research, developing technologies, and training future scientists and engineers. Universities receive \$37 billion in federal R&D funding, the largest source of funds they receive to carry out these roles.<sup>79</sup> And universities are a source of technology breakthroughs, and

many start-ups spin out of university research. For example, universities are driving many of the developments in gene-editing.

As companies are moving away from exploratory research toward nearer-term R&D that supports business units, they more frequently look outside of the firm for breakthrough innovations—and universities often fit that bill. In a recent survey of U.S. manufacturing firms, of those firms that had innovated, 49 percent reported that the invention underlying their most important new product had originated from an outside source.<sup>80</sup> In addition, research universities are increasingly expected to be drivers of economic development, serving as local sources of innovation.

Yet, years after laws were passed and incentives put in place to encourage technology transfer from universities, with exceptions, it is not in the core of their culture and often is not treated as a priority. As a function, it is often physically separated from the research enterprise, and cost pressures make the technology transfer function vulnerable. There are exceptions, for example, in the large commercial health care institutions embedded in universities.

The fundamental model of university research—its organizational form, goals, timelines, philosophy of intellectual property, and rewards—are not aligned with the needs of industry. And time horizons are often incompatible between academia and industry—with the quarterly pace of industry often at odds with longer time horizons in the academic world. Academic researchers want to publish results, while industry wants to keep results proprietary for competitive advantage. Private sector innovation is increasingly multidisciplinary, yet university research is often dominated by single discipline, investigator-driven research projects, and reward systems, publication practices, and career paths reinforce that approach. In seeking to collaborate, significant intellectual property barriers may still arise between academia and industry.

77 Leveraging America's Seed Fund, Small Business Innovation Research, and Small Business Technology Transfer, U.S. Small Business Administration, March 2020.

78 About the SBIR and STTR programs, <https://www.sbir.gov/about>.

79 National Patterns of R&D Resources: 2017-18 Data Update, Table 2, National Science Foundation.

80 Arora A, Cohen W, and Walsh J. *The Acquisition and Commercialization of Invention in American Manufacturing: Incident and Impact*. NBER Working Paper, National Bureau of Economic Research, 2016.

Companies are willing to invest in research at universities, if they can see a value proposition. However, businesses at present only spend about one-percent of their R&D investment at universities.<sup>81</sup> More problem-, challenge-, and opportunity-centered research initiatives and projects could drive change in this investment posture—as well as help broaden the culture within academia. As many emerging technologies are multidisciplinary, and problems and challenges multi-dimensional, these partnerships would focus knowledge and skills from multiple disciplines on solutions. Since such research projects would be designed with end goals and end users in mind, the technology transfer time gap—and perhaps even the valley of death—could be significantly diminished or avoided.

## RECOMMENDATIONS

To enhance their already strong contribution to U.S. innovation and economic growth, universities should seize the opportunity to make technology transfer a higher priority, develop new dimensions to their diverse research culture, and reward those who work in new ways.

- Change the incentives and rewards at universities to promote industry engagement, technology transfer and commercialization. Through their performance and compensation system, hold university leaders accountable for the success of technology transfer activities and university engagement with industry.
- Make fostering innovation, and transfer of technology and research results part of university research faculty promotion and tenure considerations.
- Employ dedicated technology transfer experts, either working at a central institution connected with multiple universities or embedded within

a university's administration, to help innovators navigate the process. Universities should ensure that sufficient funding is available to carry-out the technology transfer function.

- Federal departments and agencies should require that a small percentage of funds in each federal R&D grant to universities be devoted to technology transfer activities. The funds in each grant could be used by the Principal Investigator for such activities or provided to a central university technology transfer office.
- In developing their research projects, university researchers should factor applications and utility by end-users and customers into their development process. This could include academic and industry team engagement to develop a clear articulation of end-user applications and problem sets and changing the skill mix for university outreach to include not only Ph.D. researchers, but personnel with industry and business expertise.
- Universities should undertake work to streamline further their negotiations and intellectual property agreements with the private sector.

### Identifying Opportunities for Collaboration

Many companies, particularly small and medium-sized firms, are not familiar with the research and technology developments taking place at universities and in federal laboratories, even though some of that R&D could contribute to the companies' innovation potential.

There are models that could be modified to better engage these companies and create new connections that could spur more innovation. For example, when the Department of Defense seeks to procure a major system, it often convenes an “industry day” to inform industry of its needs. In connection with its research programs, DARPA typically hosts Proposers Days to provide information on recently released or soon to be released Broad Agency Announcements that solicit proposals. The purpose of these meet-

81 Table 2. U.S. R&D Expenditures by Performing Sector and Source of Funds: 1953-2018, and Table 6. U.S. R&D Expenditures by Source of Fund and Performing Sector: 1953-2018, National Patterns of R&D Resources: 2017-18 Data Update, National Science Foundation, January 8, 2020.

ings is to provide information on the program, promote additional discussion, and address questions from potential proposers. Some Proposers Days also encourage one-on-one meetings with program managers. In connection with the research its funds, the Department of Energy offices often hold annual peer reviews that are open to the public and provide an opportunity to learn more about the department's R&D, demonstration, and deployment projects. These reviews also provide an opportunity to promote collaborations and partnerships.

Also, such information exchanges can promote solutions that cross disciplines, that otherwise may not emerge. For example, analyzing materials in oil and gas wells down-well with laboratory efficiency was thought to be impossible. However, an optical sensor technology—originally invented to measure impurities in dog food—was ruggedized and applied to analyzing materials in wells in real time, resulting in dramatic productivity improvements.

As industry increasingly looks externally for breakthrough technologies, informational interactions between companies and the research community could spur greater co-creation of innovations.

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## RECOMMENDATION

Set the stage for future partnerships and technology transfer. Federal laboratories, universities, and industry should routinely convene mini-symposia of several days in length where subject matter experts from the laboratories, universities, and industry could each

give their views on the challenges and opportunities to scale emerging disruptive technologies, as well as the resources, expertise, and technologies available at these research laboratories and facilities. These could serve to both educate different constituencies and incubate future partnerships.

## Accelerating the Scaling of Innovations to Modernize U.S. Physical Infrastructure

Physical infrastructure is the backbone of commerce, critical to business efficiency, and a major factor companies consider when deciding where they will invest in business operations and facilities. America's infrastructure used to be the best in the world, but it is crumbling. The American Society of Civil Engineers prepares an infrastructure "report card," giving the U.S. infrastructure overall a D+. Areas of infrastructure that don't make the grade (grading a D or below) include aviation, drinking water, wastewater, energy, roads, transit, and hazardous waste. They are in poor or fair condition, with many elements near the end of their service life and deteriorating. Deficiencies in U.S. traditional physical infrastructure could cost the United States \$4 trillion in the next few years ahead.<sup>82</sup>

Congress is poised to act to increase funding for U.S. infrastructure. These investments in traditional infrastructure can improve the quality, efficiency, sustainability, and safety of bridges, roads, airports, and utilities, and provide opportunities for innovative entre-

82 Failure to Act, Closing the Infrastructure Investment Gap for America's Economic Future, American Society of Civil Engineers, 2016.

preneurs and corporations to contribute to a modern infrastructure through the next wave of advanced manufactured goods and smart technologies.

For example, new structural materials are being introduced at a rapid rate—advanced cements and steel, composites, polymers, paints and coatings—offering better corrosion resistance and durability, light weighting, heat and fire resistance, and tailored functionality. They will allow engineers to build systems and architects to design structures that were never before possible. Some materials under development will have properties so unique they offer previously unimaginable applications, for example, self-healing materials for roads and bridges. Deployment of smart grids will improve grid reliability and resilience, enhancing grid security, and providing for better energy management. Networked and automated vehicles, smart roads and highways, and data analytics could deliver an order of magnitude improvement in safety, reduced congestion, better mobility, greater sustainability and reduced transportation costs. Sensors and networks can stretch across the physical infrastructure, measuring, monitoring, and generating data to be used for diagnostics maintenance scheduling, and optimizing energy consumption. Sensors can perform remote watch, checking miles of rail track, the condition of underground water systems, or structures such as bridges and tunnels. Digital technologies can transform our infrastructure from passive structures into dynamic, smart systems that generate streams of data that can be analyzed to provide new insights into these systems, their operation and use.

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## RECOMMENDATION

Using their traditional infrastructure investments, federal, state, and local governments should drive deployment of new technologies into physical infrastructure such as high performance materials; technologies for more optimal and efficient energy generation and management; and sensor, network, and other digital and data technologies that make infrastructure smart, safer, more efficient, and responsive. Make these Investments in public infrastructure in conjunction with the research centers, start-ups, and manufacturers that are actively developing these innovations. Federal investments in infrastructure should include funds to cover additional costs of incorporating smart technologies and include points in proposal- and contract-scoring for projects that propose specific construction of smart infrastructure.

## Fueling and Financing Innovation

While the U.S. financial system for innovation, business investment, and expansion is considered to be among the most, if not the most, competitive in the world, obtaining capital at critical junctures in the innovation development life cycle can be challenging. And this is true not just for innovating entrepreneurs and smaller enterprises—even in large corporations, investments in innovation of even a few hundred thousand or a few million dollars often must be sold to corporate finance based on return on investment (ROI) thresholds and return time-lines, rather than on technical promise.

### Globally Competitive U.S. Corporate Tax Rate

Recognizing the impact high corporate tax rates have on business investment decisions, other nations have steadily lowered their corporate tax rates, with declining rates in every region across the globe including in the largest economies.

In 1980, the unweighted average worldwide statutory tax rate was 40.38 percent. In 2019, the average unweighted statutory rate was 24.18 percent—a 40 percent reduction over the 39 years. The average rate, when weighted by GDP, was higher than the simple average over this period. Prior to the U.S. tax reform of 2017, the United States was largely responsible for keeping the weighted average so high, given its relatively high tax rate, and its significant contribution to global GDP. The weighted average statutory corporate income tax rate has declined from 46.67 percent in 1980 to 26.30 percent in 2019, representing a 44 percent reduction over the 39 years. Today, most countries have corporate tax rates below 30 percent.<sup>83</sup>

The United States had a statutory corporate tax rate among the highest in the world. The Tax Cuts and Jobs Act of 2017 reduced the U.S. corporate income tax rate from 35 percent to 21 percent. When sub-central government corporate income taxes are added on top, the average combined tax rate is 25.8 percent.<sup>84</sup> The lower rate passed in the 2017 Act makes doing business in the United States signifi-

cantly more attractive, and potentially frees more private sector funds for investment. However, there is political pressure to increase the rate.

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### RECOMMENDATION

The United States should maintain a corporate income tax rate at least as competitive with the EU and OECD countries averages, 20.9<sup>85</sup> and 23.2<sup>86</sup> respectively.

### Tax Incentives for Greater Investment in Start-up Businesses

Federal tax law (Internal Revenue Code Section 1202) seeks to incentivize investment by allow a 100 percent exclusion of capital gains on long-term investments in qualified small businesses with less than \$50 million in assets that are organized as C corporations. The exclusion has not been widely adopted. Attracting greater investment in small businesses and increasing access to capital for start-ups would help spur and scale American innovations.

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### RECOMMENDATION

Congress should pass legislation to expand the scope of the Section 1202 exclusion to apply to pass-through entities and increase the \$50 million asset limit to \$100 million.

83 Corporate Tax Rates Around the World, 2019, The Tax Foundation.

84 OCED.Stat Statutory Corporate Income Tax Rates.

85 <https://tradingeconomics.com/european-union/corporate-tax-rate;>  
<https://home.kpmg/xx/en/home/services/tax/tax-tools-and-resources/tax-rates-online/corporate-tax-rates-table.html>.

86 Corporate Tax Statistics, Second Edition, OECD, 2020.

Capital for Innovators and Entrepreneurs. Start-ups and small businesses cannot grow without access to financing and other resources, and investors willing to work with the distinctive needs of small and young companies. California, New York, and Massachusetts have cultivated investors who understand the opportunities provided by small innovative companies. Collectively, these states account for 84 percent of the total venture capital and 86 percent of venture capital raised in 2019 in the United States. They also account for 73 percent of venture capital invested in 2019.<sup>87</sup> Venture capital for young, promising firms is needed to fuel economic development in more U.S. regions to address negative macroeconomic trends and economic inequality challenges. But this concentration is limiting access to venture capital for high-potential companies located in the rest of the United States, constraining innovation and economic growth. Communities in the rest of the country need tools to help unlock capital for entrepreneurs.

### RECOMMENDATION

Build local venture capital investment capacity to fund high-potential innovators and entrepreneurs in more locations and improve the performance, reach, and diversity of venture capital.

- A new National Competitiveness and Innovation Council should lead an effort to develop and provide to government entities and private companies a best-practices playbook for smart,

market-based capital formation policies and programs that leverage public and private resources to support new venture fund formation and place-based economic development.

Banking regulations and market pressures have limited the loans available to small businesses that need capital to expand. Through a small business credit program and the Community Development Financial Institutions Fund for underserved communities, the Department of the Treasury has facilitated numerous loans and investments to entrepreneurs—and many of these transactions have included banks, funds, and other private capital. A Startup Capital Investment program should be developed that leverages private financing to make new investment in America's manufacturers and other growing businesses to create new employment and investment opportunities throughout the country.

### RECOMMENDATION

Modernize the Department of the Treasury's small business capital programs to emphasize bank loans and private investments into American manufacturers and thousands of other small businesses and startups.

Several federal agencies provide funds to communities, nonprofits, and others to establish revolving loan funds focused on specific businesses and projects. The potential impact of these programs to fuel the growth of start-ups and small businesses is stymied by a restriction on the use of these funds just for basic loans or, in some cases, loan guarantees. If

these funds and programs provided capital that could be used by the recipient for debt and equity tools, then a wider variety of businesses and projects could be assisted, and greater overall economic impact and returns for the programs could be achieved. While equity investments often carry greater risk than debt, the implications for federal funds would not change. Intermediary lending programs—such as the Economic Development Administration’s Revolving Loan Fund, Small Business Administration’s Microloan program, and U.S. Department of Agriculture’s Intermediary Relending Program—provide either grants, in which case any loss of funds is irrelevant to the federal cost, or through loans to the fund with penalties for non-repayment; but, as these repayments are not required to be made with the original federal dollars, the intermediary could also repay any lost investments with its private match.

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### RECOMMENDATION

Revise the regulations of federal small business-focused intermediary lending programs to allow equity investments into businesses.

- Congress should authorize existing federal economic development programs that currently provide traditional loans and loan guarantees—in the Economic Development Administration, the Small Business Administration, and the U.S. Department of Agriculture—to allow these funds to be used for equity investments and other early-stage capital to better support small business innovators and start-ups.

Despite their sacrifices, America’s returning service members often struggle to acquire the capital they need to establish their own business—a problem shared by many women and minorities. Targeted programs, such as the Small Business Administration’s Veterans Advantage, designed to provide competitive awards and leverage private capital, offer these individuals a path to entrepreneurial success and should be supported throughout business-related federal agencies.

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### RECOMMENDATION

Federal agencies supporting direct or intermediary lending and investment programs should develop special rates or set-asides to further assist veterans and other underserved populations.

- Implement policies and guidance to encourage federal economic development programs (e.g., Small Business Administration, Economic Development Administration, U.S. Department of Agriculture, and Department of Housing and Urban Development) to specifically facilitate grant, loan, and investment opportunities to veteran, minority and women entrepreneurs.

For most of the last decade, federal science and technology budgets have stagnated with deleterious impact on research and innovation, and the subsequent movement of ideas to market. And while corporate spending on research and development has increased, the emphasis has been placed on product development and short-term outcomes, severely constraining its reach and impact. While

most high-technology companies rely on the fruits of long-term scientific research, stockholder demands for short-term profits and lower risk, and executive compensation based on increases in share prices make it virtually impossible for companies to make their own longer-term investments in research and innovation. Instead, they rely on—and often advocate for—federal support of such activities. They should champion another opportunity to spur the discoveries and innovations they cannot fund in their corporate laboratories.

The combination of flagging federal support for science, innovation, and commercialization and the reluctance of industry to invest in long-term research and innovation compromises U.S. economic growth, which depends overwhelmingly on science and technology. As a result, the United States is at a competitive global disadvantage, as European and Asian competitors ramp up directed spending on targeted science, emerging technologies, and innovation.

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## RECOMMENDATION

Congress should establish an endowed, non-profit American Innovation Investment Fund (AIIF), a private-public partnership with an initial capitalization of \$100 billion, to fill the funding gap between science and technology, and the market. The AIIF would be launched with corporate contributions encouraged through tax incentives, and potentially matched by federal funding. The fund could:

- Stimulate the movement of research to market, and jump-start large research projects that often languish for years as they wade through agency and congressional approval processes or cross agency boundaries.
- Help bridge the “valley of death” by funding applied research that does not fit industry’s or government’s strategic goals and permit a focus on opportunities that do not align neatly with agency missions.
- Target groups and regions of the United States with historically low access to capital.
- Offer companies an opportunity to underwrite long-term research and innovation through a tax-free contribution.

10x

**A NEW INNOVATION AGE CALLS FOR A NEW INNOVATION GAME**

# 10x: Increasing the Number and Diversity of Americans Engaged in Innovation

Large parts of our population—including many urban youth, rural Americans and communities without research institutions—do not see themselves as part or beneficiaries of the innovation ecosystem. Yet, there are many talented and resourceful problem solvers—young urbanites, rural farmers, makers and tinkerers, etc.—who are not viewed by others, and who do not view themselves, as part of an innovation or entrepreneurial ecosystem.<sup>88</sup>

Despite this perception, the United States has significant untapped entrepreneurial potential. Sixty-five percent of the U.S. population 18-64 years of age who are not involved in any stage of entrepreneurial activity believe they have the required skills and knowledge to start a business, well above the global average of 58 percent. Yet, only about 13 percent of these latent entrepreneurs intend to start a business in three years, well below the global average of nearly 24 percent.<sup>89</sup>

We are not engaging the full potential of our citizens to drive innovation for the whole country, and the benefits of the innovation economy are not reaching many in our population. Moreover, the full demographic of the country is not being prepared to contribute to the innovation economy and is not receiving shared benefits from this economy either.

To raise the U.S. rate of innovation, and to create a more inclusive innovation economy that generates wealth and jobs for all Americans, we must engage more Americans and more U.S. regions in the innovation process.

## Expanding the U.S. Map of Innovators

While America's well-known hubs of innovation are mostly located on the coasts, every region in the United States, large or small, possesses assets that can be leveraged for economic gain. These concentrations of intellectual capital can generate inventions, discoveries, innovations, and ideas for new products and services that hold the potential to drive new, high-growth business formation and job creation in these regions. While it is true some regions are better endowed with innovation assets than others, increased innovation capacity starts with an improved understanding of regional assets and deficits.

To expand the U.S. capacity for innovation in the face of strengthening global competition and engage more Americans as innovators, the United States must capitalize on these geographically-diverse sources of innovation and not leave significant sources of promising creativity and innovation untapped. Increased innovation capacity starts with improved understanding of regional assets and deficits.

88 Transform, A New Agenda to Boost U.S. Innovation-Driven Competitiveness in the 21st Century, Exploring Innovation Frontiers Initiative, Council on Competitiveness, 2017.

89 GEM Global Entrepreneurship Monitor

## RECOMMENDATION

Regions should develop a frank, data-rich assessment of community capacity for innovation, including a clear definition of the region, strategies to assess sectoral strengths, intellectual property, education and human resource capacity, infrastructure assets, quality of life considerations and other key elements. Use this assessment to inform the development of data-driven public-private strategies to link systematically innovation-supporting resources, address deficits, identify value-adding capabilities, acquire needed resources, and effect change.

### Federal Investments in Economic and Community Development

The federal government—including the Departments of Agriculture, Commerce, Housing and Urban Development, and Labor, the Small Business Administration, and other federal agencies—invests billions of dollars in economic and community development, and worker training in distressed and underdeveloped urban, rural, and de-industrializing communities. This includes funding for a range of business development, innovation ecosystem development, physical and digital infrastructure, training for careers in high technology industries, renewable energy systems, and state, local, and regional organizations and initiatives that work to foster economic development and job creation in these communities. However, this fragmentation fails to optimize and integrate these investments in building the innovation ecosystems, and innovation and advanced manufacturing industry-ready workforce in these communities.

## RECOMMENDATION

Congress should restructure federal economic development, community assistance, and related training programs into a performance and block-grant-based program to eliminate fragmentation and suboptimal approaches, in favor of strategic and integrated efforts with critical mass that:

- Establish regional competitiveness and thriving innovation ecosystems as the overriding goals of economic development investments
- Target resources on communities and regions with the greatest need
- Encourage communities to form regional alliances based on economic relationships rather than political boundaries
- Apply analytical tools and metrics to identify their competitive advantages and innovation assets, develop strategies, track progress, and quantify performance outcomes
- Connect aspiring innovators and entrepreneurs in distressed communities to innovation assets at universities and federal laboratories, financing resources, knowledge and skill development, mentoring, etc.
- Build capacity for competing for research and technology development grant assistance
- Coordinate and consolidate workforce development programs with economic development initiatives
- Undertake efforts to encourage private investment and business expansion

### Breathing New Life in Declining U.S. Regional Economies by Stemming the Brain Drain, Injecting High Skills, and Raising Innovation Potential

High-skill occupations are more concentrated in U.S. urban areas. These urban areas tend to be more innovative, have more economic activity and faster economic growth, and workers earn higher wages. In contrast, occupations more prevalent in rural and rust belt areas are those with lower skills and hands-on jobs.<sup>90</sup>

Communities outside of U.S. technology hubs—such as those on the U.S. coasts—struggle to capture innovation talent, especially in the form of entrepreneurial startups, resulting in lower rates of innova-

90 Workforce Skills Across the Urban-Rural Hierarchy, Jaison R. Abel, et.al., Federal Reserve Bank of New York, February 2012.

tion-based jobs and companies. These communities lose their home-grown talent when graduates from local colleges and universities make their careers away from their local community.

On average, community college graduate stay within 300 miles of their college, and nearly two-thirds stay within 50 miles. Graduates of state schools stay an average of 330 miles from their schools, 40 percent within 50 miles of the university. In contrast graduates of elite schools tend to move much further from their universities, an average of about 700 miles away, and tend to settle in urban areas and hubs of economic activity. In addition, high school graduates with higher SAT scores and GPAs tend to travel much farther away from home to attend college than those with lower academic achievement.<sup>91</sup>

In addition to place-based opportunity, opportunities are not always equally available to all communities. For example, economists have estimated that U.S. GDP could be 3-4 percent higher with greater inclusion of women and underrepresented minorities in the innovation process.<sup>92</sup>

Increasing the number of graduates remaining closer to home after graduation could grow the talent base needed for building a knowledge-based, innovation-driven regional or local economy. While talent is the most critical ingredient in the process of innovation, other elements of the ecosystem must be in place or developed to harness this talent. This includes ongoing communications among educators, employers, students, and workers to ensure education and training programs are developing a workforce that is job-ready and sensitized to a lifetime of learning and evolving work and career opportunities. High-speed networks and broadband capability are needed to access online resources for work and education, and traditional infrastructure to underpin

the economy, for example mass transit to help connect students to education institutes and workers to job opportunities.

## RECOMMENDATION

Local universities, companies, and business associations should collaborate to develop the innovation ecosystem and skill base of innovators, providing opportunities and support to college and university students during their academic experience to encourage these students to remain in the community as entrepreneurs and business leaders. Numerous tools and economic policies are in the kit to develop a strategy and ecosystem operating along the continuum of innovator development and retention:

### K-12

- Prepare all students for STEM innovation with a rigorous, engaging and immersive curriculum that involves experiencing innovation and invention beginning in elementary school.
- Sponsor Tech Olympiads, invention projects, and competitor, similar to Science Olympiads, for elementary and middle school students to get students them on the road to innovation.
- Establish apprenticeship programs starting in middle school to teach students soft skills and provide help with career planning and navigation. The “Jobs of the Future” initiative, a partnership between the U.S. Department of Labor and Scholastic, offers a model.<sup>93</sup>
- Incorporate career and technical education as part of high school curriculum or as after-school activities.

### Post-Secondary

- Federal and state governments could provide incentives—such as tuition rebates or scholarships—for students to remain in, or close to, the home community with tuition rebates or scholarships.

91 Student Choice of College: How Far Do Students Go for an Education?, Dr. Krista Mattern and Jeffrey Wyatt, *Journal of College Admission*, Spring 2009.

92 Lost Einsteins: Lack of Diversity in Patent Inventorship and the Impact on America’s Innovation Economy, Dr. Lisa D. Cook, Michigan State University, Testimony Prepared for Hearings Before the Committee on the Judiciary, Subcommittee on Courts, Intellectual Property, and the Internet, U.S. House of Representatives, March 27, 2019.

93 <http://www.scholastic.com/jobsofthefuture/index.html>.

- Colleges and employers should work together to create elective curricula relevant to local industry needs.
- Create local and regional accelerators and competitions, with associated technical assistance, for students at institutions of higher education launching innovation-based businesses. Businesses, foundations, and philanthropists can support, sponsor, or operate these accelerators and competitions. San Diego's CONNECT, Invent Oregon, and the multi-state Clean Tech Alliances are models to explore.<sup>94</sup>
- For both students and local first time entrepreneurs, local businesses and universities can provide access to equipment and facilities at discounted rates.

### **Building Ecosystems that Can Develop New Innovators, and Spur Innovation-driven Economic Opportunity and Higher Standards of Living in Underserved Communities**

Many minority communities with high levels of poverty are disconnected and do not benefit from the U.S. innovation system, despite the fact that many are located in urban areas with proximity to prominent research universities, engineering schools, and high technology companies. These communities too often lack built, social, and digital infrastructures needed to create economic opportunities and jobs, localized production systems that can connect to national and global supply chains and integrate their citizens into the U.S. innovation ecosystem. As starkly demonstrated during the COVID-19 pandemic, the absence of these essential assets for community prosperity, stability, and resilience has led to low food security, work in low paying jobs threatened by automation, and a digital divide that further afflicts an already challenged educational system where STEM competencies lag.

Research and engineering initiatives focused on the needs, challenges, and opportunities in these communities—and carried out by diverse and inclusive leaders and stakeholders within them—could increase their connection with the U.S. innovation system, encourage greater participation in STEM studies and the STEM workforce, and result in the user-centric development and design of technologies and solutions that can serve as the basis for start-up businesses and entrepreneurial opportunity in the community. Those working on user-centric technology and solutions within the cultural context of the community would learn to recognize and address their own biases that may contribute to the disenfranchisement of these communities or biases embedded in technologies such as artificial intelli-

### **Early/Mid-Career**

- Encourage businesses to provide incumbent workers training through tax incentives.
- Encourage university technology transfer offices to work with their research faculty and staff to take their ideas to market by leveraging supportive programs like the National Science Foundation's iCorps program, and by providing market information and intellectual property advice. Where they are absent, establish technology transfer offices at minority-serving institutions, including Historically Black Colleges and Universities, as well as Appalachian Colleges, and other regional colleges that support students who are underrepresented in innovation. Like students in community colleges, many of these students are also more likely to go to school closer to home, and these offices would leverage the research activity of these underserved students. Further, faculty and staff should be encouraged to include student-entrepreneurs in those startup activities.
- Create a startup fund focused on creating companies that address local business needs. Business associations such as Life Science Association of California (BIOCOM) can provide advice and assistance. Engagement by local universities will create opportunities for local researchers, including students.

gence, functional foods, personalized learning, user interfaces, transit system technologies, etc. That provides a powerful education for all of those who seek to create products, services, and solutions for these communities, as well as for different cultures around the world.

## RECOMMENDATION

Within communities of dire social and economic need, a coalition of stakeholders—universities, community colleges, community organizations, State and local governments, NGOs, industry, K-12 schools, and small and medium size enterprises—should establish multidisciplinary engineering innovation centers and ecosystems.

- Work carried out in these centers and ecosystems should be based on data-driven analyses of challenges and opportunities in the community and seek to achieve progress toward goals that matter to people such as reduced poverty, hunger, and homelessness.
- Technology and solution development should drive progress toward these goals—for example, enhanced nutritional intake and increased physical activity—and the development of technologies within the cultural context for which they will be applied and used.
- Multidisciplinary approaches will help address multi-faceted challenges, for example, at the nexus of food, environment, water, and health.
- The centers should engage the communities in which they reside for STEM learning, for example, in K-12; provide experiences and role models for youth interested in science and technology; and provide innovators, entrepreneurs, and STEM students with mentoring and assistance accessing facilities and equipment to advance their ideas and technologies.
- Centers should establish linkages with regional initiatives focused on cultivating innovators and entrepreneurs through training, incubators, accelerators, venture funding, etc.

## Developing New Innovators

The U.S. education system risks growing increasingly out of step with the needs of work in the 21st century knowledge and innovation-based economy and society. This disconnect is reflected in the size of the displaced workforce lacking the skills and preparation to fill the available and growing number of jobs in the innovation and high-technology sectors. It is reflected in the paucity of women and minority inventors and entrepreneurs, and in the C-suites and boards of companies. It is reflected by data that suggest we are not fully tapping our invention potential and that, if “women, minorities and children from low-income families were to invent at the same rate as white men from high-income families, there would be four times as many inventors in America as there are today”—with associated economic benefits to individuals and the Nation.<sup>95</sup>

To be competitive at a global level in the future we need to tap the full innovation potential of our population. That will require increasing investment in education and changing our education process to cultivate the associated mindsets and skill sets needed to promote invention, entrepreneurship and innovation talent, as well as ensure that such educational programming reaches all students as they prepare for careers and life-long learning. There must be intentional consideration of the approach and content in those programs to ensure it is inclusive for girls and students from minorities under-represented in the innovation fields. Further, education systems should not be expected to take on this work alone. Rather, industry, government and other sectors have important roles to play in partnering with educational systems to foster innovation talent, beginning with Pre-K.

95 “Who Becomes an Inventor in America? The Important of Exposure to Innovation,” Alex Bell, Harvard University; Raj Chetty, Stanford University and NBER; Xavier Jaravel, London School of Economics; Neviana Petkova, Office of Tax Analysis, U.S. Treasury; John Van Reenen, MIT and Centre for Economic Performance; December 2017.

### The Innovator Mindset

Many people think that innovation is important only to “technical” careers, those based in science, engineering, or technology. If you are not working in R&D or developing software, innovation is not your responsibility. Many Americans do not think of themselves as potential innovators either. This constrains American innovation in two ways. First, it may stifle a person’s willingness to be innovative if they don’t see themselves as highly educated, in a research or engineering role or part of a “high-technology” business. Important and potentially revolutionary breakthroughs in business models, employee programs, services delivery, financial matters—and in a wide range of other domains—may not be explored. Second, if managers hold this limited definition of innovation, they may not encourage behaviors that lead to new business models or other innovations that could benefit the company or increase its competitiveness. For example, Toyota employees have submitted tens of millions of suggestions to improve the company’s operations.<sup>96</sup> The future of U.S. competitiveness depends on continuing our innovation leadership. One way to expand that leadership is to see innovation beyond science and technology to include innovations in a broad range of domains including business, education, philanthropy, government, investment, and more.

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### RECOMMENDATION

Those leaders and experts involved in innovation-related activities should remove the perception that innovation is limited only to careers in science, engineering, or in “high-technology” companies—and support efforts such as the “Science Is US” campaign in which the Council on Competitiveness is a key leader along with nine other major, national organizations at the forefront of STEM advocacy.

### Education for Invention and Innovation

A growing community of educators has recognized that experiencing invention, innovation and the fundamentals of entrepreneurship across the K-12 and higher education journey can enhance learning, particularly around STEM, design and adjacent disciplines; open minds and possibilities by fostering student creativity, self-efficacy, and a sense of belonging; and prepare students with the mindsets and skill sets that CEOs are seeking in their future workforce, while further cultivating future inventors and entrepreneurs. Industry partnerships, and the range of resources that they bring, will be key to realizing this goal.

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### RECOMMENDATION

The education community, supported by government at all levels, should ensure that every student has the opportunity to experience invention and innovation throughout Pre-K-12 and higher education, and interested individuals have accessible pathways to develop their skills and ideas.

- Implement a continuum of broadly accessible experiences—from K-12 to post-graduate—that engages learners in inventing from an early age and encourages the formation of an identity as an innovator, building knowledge, confidence, and a sense of belonging in the world of science, technology, and innovation.
- Establish standards across the continuum of K-12 to higher education that strongly encourage age-appropriate experiences in inventing (including integrated immersive experiences in invention, innovation, and fundamentals of entrepreneurship), and computer science for all students, regardless of geography, gender, ethnicity, race, or background.

<sup>96</sup> [https://www.toyota-global.com/company/history\\_of\\_toyota/75years/data/company\\_information/management\\_and\\_finances/management/tqm/change.html](https://www.toyota-global.com/company/history_of_toyota/75years/data/company_information/management_and_finances/management/tqm/change.html).

- Establish and deepen federal, state and local government—as well as corporate—support and investment in partnerships and programs that foster invention education and computer science in primary and secondary schools (including support for educator training and integrating relevant curricula, physical facilities, and resources into existing requirements and curriculum).
- Increase support for capturing quantitative and qualitative data on the outcomes of student engagement in invention education and computer science in primary and secondary education, for example, participation levels in entrepreneurial activities, fairs and competitions; assessments of mindset and skill sets; portfolio assessments; future career trajectory; etc.
- Have accreditation bodies such as ABET revise their accreditation requirements for science, engineering, technology, and business programs in higher education to drive the integration of basic topics in innovation, entrepreneurship, and commercialization more broadly into these programs' curricula.
- Encourage institutions of higher education to increase incentives and funding to enhance their support for collegiate innovators wishing to launch new enterprises by leveraging existing models for experiential innovation learning.

### Targeted Efforts to Enhance Diversity and Inclusiveness

In the United States, individuals with an education or degree in science, technology, engineering, or mathematics play a critical role contributing to innovation in companies, and as founders of innovative start-ups. Yet individuals from economically disadvantaged urban areas are grossly underrepresented in the STEM workforce. This underrepresentation of STEM workers from low socio-economic strata, and poor urban and rural areas limits the opportunity for this demographic segment to pursue workforce oppor-

tunities in these high-wage occupations and in high growth, STEM-worker intensive industries, impeding progress toward diversity and inclusion in society.

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### RECOMMENDATION

Partnerships of high school math and science department chairs, companies in the information technology and science fields, and corporate volunteers should identify talented high school math and science students from low-income areas and provide assistance, coaching, and mentoring to them from high school through college to STEM careers.

- Begin a pilot project in one or more cities across the United States (for example, Baltimore, Philadelphia, Detroit, St. Louis, Chicago, et al.)
- Select a group of high performing 10th graders in math and science, and provide them with mentoring, guidance, a financial stipend (funded by companies) through high school and college, as well as internships and job placement upon graduation.

### Connecting Underserved Communities and Populations to the Federal Research and Technology Development Funding Pipeline

Diversity enables innovation. It is the source of developing the widest and most diverse set of potential solutions for complex and challenging problems, and identifying new pathways for discovery and breakthrough technologies. Diverse teams working together can capitalize on distinct perspectives.

However, some communities and underrepresented populations—including underrepresented minorities pursuing STEM fields—often do not connect with opportunities to participate in Federal research and technology development, or the Federal funding streams that could support their research and innovations. The Federal government is a major of funding for university researchers, for example, through the National Institutes of Health, Depart-

ment of Defense, and Department of Energy (DOE) Office of Science and, for small innovative firms, for example, through the Department of Defense and DOE programs focused on clean energy and energy efficiency technology development. Federal departments and agencies have increased their focus on increasing the diversity of their pool of grantees, but more can be done to connect these communities and populations with these funding streams.

## RECOMMENDATION

The NCIC, Federal departments and agencies, universities with significant populations from groups underrepresented in STEM, state and regional economic development entities, and organizations focused on advancing minority-owned small and start-up businesses should take further steps to connect these communities to the Federal research and development funding pipeline:

- The NCIC should establish “ambassadors” to convene “road-show” workshops at these universities and in these business communities that present the R&D grant opportunity landscape across the Federal government, with information on the types of grants available, technical areas of interest, typical grant size, proposal requirements, how to access calls for proposals, etc.
- State and regional economic development entities should build the capacity to and provide mentoring and technical assistance to underrepresented minority-owned small and start-up business in the development of proposal concepts and project teams, and in preparing competitive proposals in response to open Federal R&D funding opportunities, including the Small Business Innovation Research Program. Organizations focused on advancing minority-owned small and start-up business should also provide this assistance.

- Organizations focused on advancing minority-owned small and start-up businesses in particular fields or industries should engage these businesses in coalitions, and negotiate umbrella Memoranda of Understanding, and umbrella Cooperative Research and Development Agreements to streamline grant and funding engagements with relevant Federal departments and agencies. These coalitions could also form consortia to pursue funding opportunities under Department of Defense Other Transaction Authority[1] consortia.
- Historically Black Colleges and Universities, Hispanic-serving Colleges and Universities, and other minority-serving institutions should consider joining Department of Defense Other Transaction Authority Consortia (if they are not currently members) aligned with the college or university’s STEM programming and STEM student body. In addition to competing for technology development grants through these consortia, establish initiatives to network with the companies that are members of these consortia to enhance the potential for project teaming opportunities and post-graduate employment.

## Supporting Inventors and Innovation Entrepreneurs Turning Ideas into Products and Businesses

The needs of innovation-based businesses, particularly those that create physical products, are not adequately supported in most regional ecosystems. For example, all businesses need a place to exist, but innovation businesses that build physical products need more than a desk and a wireless connection. They have unique needs throughout their life cycles, such access to physical space with engineering equipment or lab space, the right types of mentoring, guidance on regulatory issues and manufacturing, and patient and more substantive capital along the journey from idea to product to scaling up.

Not all entrepreneurs have equal access to even the resources that currently exist. For example, only about two percent of total venture capital in the United States flows to firms with all female founders, and about 13 percent to firms with at least one female founder.<sup>97</sup> A recent study found that just one percent of venture-backed company founders were black.<sup>98</sup> In addition, investment and talent development for early-stage entrepreneurs and early-stage investors has been primarily focused on the coasts and in known technology hubs such as Austin, Boston, and Silicon Valley.

While recent years have seen wider recognition of talent in other parts of the country, achieving full equity requires accelerated investments in underserved. Expanding numbers of new innovation enterprises with a broader diversity of founders and leadership will contribute to a more resilient economy and technological innovations that can drive competitiveness.

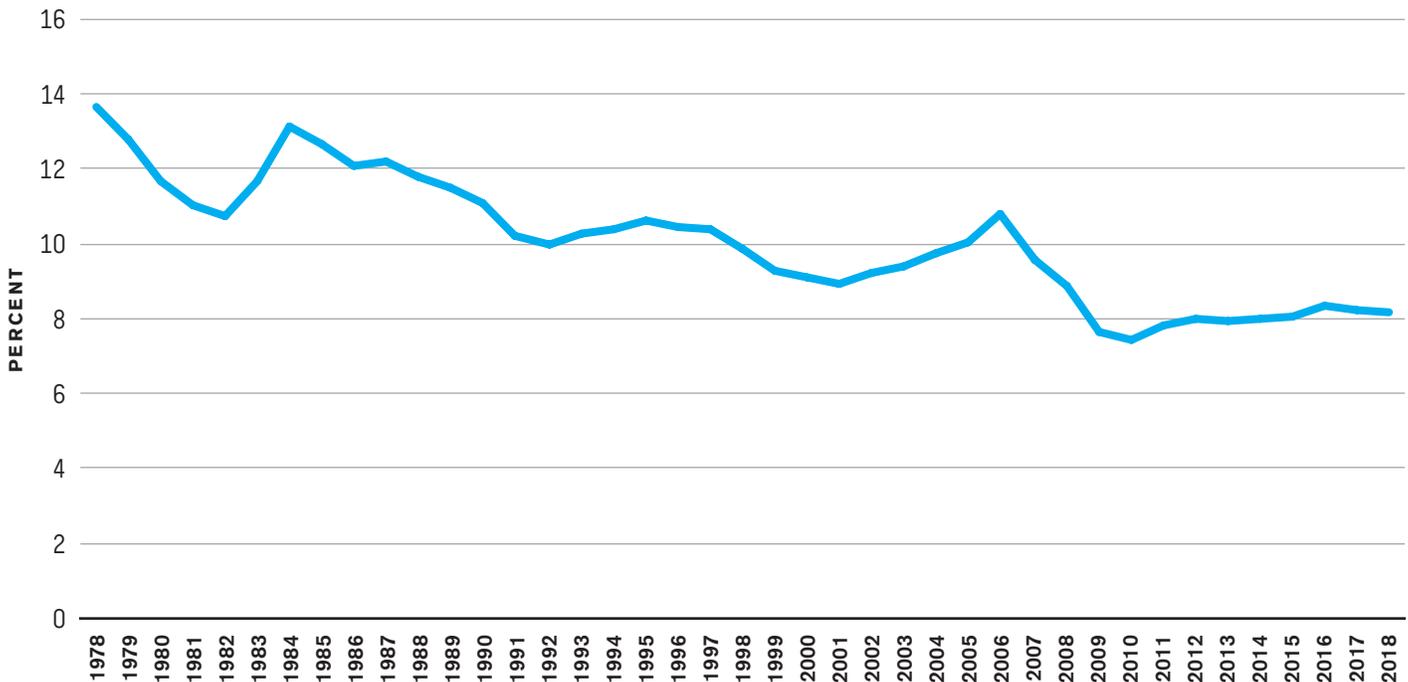
## RECOMMENDATION

Deepen support for approaches that successfully help cultivate innovation entrepreneurs, including those creating new physical products. Create more inclusive paths to support women, underrepresented minorities, and first-time entrepreneurs. Activities should be carried out with a clear equity agenda, focused on underserved geographic areas of the country and populations underrepresented in STEM disciplines, the science and technology ecosystem, and its innovators.

- Shift resources towards consistently high-quality STEM education that includes curricula on entrepreneurship and entrepreneurial skill-building within the research-oriented program context to broaden career opportunities for STEM graduates and enhance the broader science, engineering, and technology workforce with skills in design, innovation and entrepreneurship.

## Figure 12. Startups as a Share of All Firms

Source: Business Dynamic Statistics, U.S. Census Bureau



97 Venture Monitor, Q3 2020, National Venture Capital Association.

98 Diversity in U.S. Start-ups, RateMyInvestor, [https://ratemyinvestor.com/pdfs/full?file=%2FDiversityVCReport\\_Final.pdf](https://ratemyinvestor.com/pdfs/full?file=%2FDiversityVCReport_Final.pdf).

- Congress should provide more funding to the National Science Foundation-originated Innovation Corps (I-Corps) program which helps researchers gain valuable insight into entrepreneurship, starting a business or industry requirements and challenges.<sup>99</sup>
- Federal, state, and local governments, and regional innovation initiatives should provide funding and other resources at the state, regional, and federal level to mentor start-ups to better prepare them to participate and compete in the federal Small Business Innovation Research Program and other federal research and technology development programs
- Reauthorize the Small Business Innovation Research and Small Business Technology Transfer programs (SBIR/STTR) beyond 2022 and increase the SBIR/STTR set aside at all federal departments and agencies that participate in these programs. Create program opportunities and explore how to revise review panel guidelines and criteria in ways that will increase the participation of women, minority and first-time entrepreneurs.
- The federal government should expand and replicate programs the open access for entrepreneurs to federal research and laboratory facilities such as those in the U.S. Department of Energy's National Laboratories (i.e., Cyclotron Road, Chain Reaction, and Innovation Crossroads). Universities should establish or expand similar programs to host innovators and entrepreneurs in their laboratory facilities.
- Create state and federal programs and incentives for experienced innovation entrepreneurs to mentor and support novice innovation entrepreneurs from all backgrounds, building on the lessons learned from successful mentoring programs such as the Venture Mentoring Service at the Massachusetts Institute of Technology, and TiE, a global mentoring network, with associated public recognition programs for mentors. Leverage virtual meeting tools to allow these mentor and support relationships to be leveraged regardless of geographic proximity.
- The federal government should enable open access to federally-funded data sources that could enable product development such as the National Institutes of Health's All of Us program ([allofus.nih.gov](http://allofus.nih.gov)), which aims to collect electronic health records data from one million Americans and share this anonymized data with health researchers to develop treatments for diseases.

### Turning “Want”-repreneurs into Entrepreneurs

The United States has significant untapped entrepreneurial potential. Sixty-five percent of the U.S. population 18-64 years of age who are not involved in any stage of entrepreneurial activity believe they have the required skills and knowledge to start a business, well above the global average of 58 percent. Yet, only about 13 percent of these latent entrepreneurs intend to start a business in three years, well below the global average of nearly 24 percent.<sup>100</sup>

There are many programs across the country that give a hand up and help one discover the pathway to becoming an entrepreneur. But all too often, would-be entrepreneurs never even try. A range of barriers may stand in their way. These include: insufficient access to capital, expertise, and capabilities; financial challenges such as school loans and

99 Barring the adoption of this report's broader recommendations around systemic economic development reform, other actions could be explored, like: (1) providing more funding to the U.S. Department of Commerce Economic Development Administration's Build to Scale Program for strengthening venture capital and industry support within regional innovation ecosystems; and the Small Business Administration's Regional Innovation Clusters Initiative focused on providing financial, technical, and administrative support to early seed companies in geographic areas that need to strengthen their innovation ecosystems; and (2) implementing policies and guidelines that encourage Federal economic development programs specifically to facilitate grant, loan and investment opportunities to first-time, minority and women entrepreneurs (SBA, EDA, USDA, U.S. Department of Housing and Urban Development, etc.)

the need for consistent paychecks; difficulty finding people with the right skills; immigration policies that keep talent out; onerous taxes and regulations; and the need for life-balance and security, for example, healthcare and benefits.<sup>101</sup>

Start-up firms inject new vitality into the economy. But their share of all U.S. firms has been on a decline.

To increase the number of innovative start-ups in the United States, barriers to becoming an entrepreneur must be reduced, allowing them to focus on developing their products and services, building their businesses, and addressing the inherent risks of becoming an entrepreneur.

## RECOMMENDATION

Governments, associations, and professional organizations should identify best practices, and deploy solutions to remove barriers that impede aspiring innovators and entrepreneurs in starting a new business. Approaches include:

- State governments, industry associations and businesses should form alliances to create affordable healthcare and insurance programs for entrepreneurs in their regional communities.
- Income-based repayment plans for student loans can help reduce the financial burdens that may prevent young talent for starting their own business or joining a start-up firm.
- Open access to capabilities, expertise, stipends, the investment community, facilities, and equipment, for example, access to high performance computers, laboratories, high hazard safe workspaces, or specialty tools and manufacturing. This includes programs that can be implemented in the national laboratory system, at universities, and in industry innovation centers to help an entrepreneur with access to resources needed to advance, test, and validate their innovations.

## Health Trust

Source: <https://www.cleantechalliance.org/health-trust/>

Washington State recognized that not having access to affordable healthcare was a deterrent for entrepreneurs to leave the safety net of a larger firm that provided healthcare and other benefits. The independent CleanTech Alliance's Health Trust offers 17 healthcare plan options with deductibles that range from \$200 to \$8,000. Health Savings Account (HSA) plans are also available. The program offers, medical, vision, dental, life insurance, and employee assistance options.

- Lab-Embedded Entrepreneurship Programs such as Cyclotron Road at Lawrence Berkley National Laboratory, Chain Reaction at Argonne National Laboratory, and Innovation Crossroads at Oak Ridge National Laboratory—which host entrepreneurial scientists and engineers within U.S. national laboratories to perform early-stage R&D that may lead to the launch of high-tech businesses, provide mentoring, and connect participants with innovation ecosystem partners needed to facilitate commercial and investment opportunities—should cast their nets widely for candidates, beyond the elite schools and graduate programs, to engage more women and people from groups underrepresented in science, technology, and innovation.

## Industries of the Future

U.S. competitiveness, economic prosperity and national security require a workforce with the training and expertise to develop, manufacture, deploy, operate, and maintain cutting-edge technologies. However, current federal workforce development programs are insufficiently scoped and resourced to provide the workforce required by industries of the future such as biotechnology, advanced manufacturing, quantum, artificial intelligence, and others.

101 Where the Jobs Are: Entrepreneurship and the Soul of the American Economy, John Dearie and Courtney Geduldig, Wiley, 2013.

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## RECOMMENDATION

Triple funding for successful workforce development efforts supported by the U.S. Department of Energy—such as fellowships, career awards, and energy workforce development—and consider scaling best practices and programs to other agencies.

- Ensure federally-funded fellowships and early career awards programs are used to build a more diverse research and development workforce at the national laboratories and beyond.
- Identify and apply novel approaches and programs to specifically advance workforce preparedness for the “industries of the future” R&D areas.

### Developing the Next Generation of Sustainability Innovators

Global environmental challenges are among the most pressing social and economic issues we face. The products, structures and services humans design, build, distribute, consume, and throw away play a major role in creating these challenges. Minimizing the negative consequences of the resource consumption and use to produce products and services requires that innovators and talent working at businesses be equipped to anticipate and avoid those consequences.

Engineers impact nearly everything human-made, and all engineers—no matter what subdiscipline—must be equipped to protect our planet and the life it sustains. Yet, engineering students are not ubiquitously prepared with the fundamental skills,

knowledge, and competencies needed to effectively navigate the constraints of our planet’s environment, even though everything they do in their careers will potentially have environmental impact.

Similarly, business leaders devise the pathway leading to a viable business, including making decisions about which products to make, and how they are designed, manufactured, and delivered. They must weigh the impact on final business outcomes of integrating sustainability considerations in product development and operations to create value while minimizing potential negative consequences. Yet, business students currently are not required to study sustainable business practices.

To have the talent pool we need to establish sustainable production and consumption as a core competency in businesses requires a fundamental change in the approach to preparing the engineers and business leaders of tomorrow. This includes integrating cross-disciplinary environmental responsibility into engineering and business education. Some faculty, university leaders, and academic institutions are seeking to achieve this change in the engineering and business disciplines, but they need resources and tools to support, scale, and accelerate curricular transformation in the face of this urgent and growing need.

### Beyond Engineers and Business Managers

Engineering and business education and training can provide the proving ground for training in sustainability, and those disciplines represent one of the most important leverage points for addressing the

sustainability challenge. However, in the long term, training in sustainability should be integrated into all disciplines. Sustainability is an issue across the entire product value-chain and life-cycle—materials sourcing, production, packaging, distribution and warehousing, delivery to customer, customer use, and final disposition—as well as the built environment and the systems human use every day. Many other disciplines play a role, from designers, architects, procurement specialists, and industrial economists to behavioral science researchers, energy managers, marketers, public policy makers, and more.

Some higher education institutions are leading the way. For example, Arizona State University established the Nation's first school of sustainability, offering both undergraduate and graduate programs and degrees in sustainability, including specialized programs in sustainable food systems, global sustainability science, sustainability leadership, and sustainable energy. Most of its graduates are working in sustainability careers.

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## RECOMMENDATION

Academic institutions should prepare all graduating engineers and business students to be literate in systems thinking and the issues of sustainability, as well as prepared with relevant tools to promote environmental responsibility:

- Government, industry, and philanthropic organizations should organize, sponsor, and launch programs to provide support for institutions of higher education to integrate environmental

responsibility and sustainability into the required coursework for every engineering and business student. This should begin with creating faculty development programs to integrate sustainability into the curriculum of engineering and business schools but be expanded over time to incorporate other graduate and professional disciplines.

- Universities should reward faculty for integrating sustainability and promoting curriculum change and educational experiences in sustainability for engineering and business students.
- Accreditation bodies such as ABET should require and advocate for sustainability and environmental responsibility training embedded in the curricula for all engineering and business students.
- Businesses should work with universities in developing and transforming curricula to meet business enterprise needs for sustainability skills.
- Government agencies that play a role in curricula development or execution—for example, through programs to develop STEM talent, or the National Science Foundation's Advanced Technological Training program—should establish initiatives to provide support for curricular change.

# Conclusion

*Competing in the Next Economy* is a roadmap for policymakers to follow. It marks a path to innovation leadership, growth, speed and inclusivity. The roadmap acknowledges key truths:

- Other nations are replicating the structural advantages that historically have made the United States the center of global innovation;
- Many nations are developing their own, distinctive innovation ecosystems;
- The nature of innovation is changing—becoming dramatically more interconnected, turbulent and fast-paced;
- New research and business models are emerging, allowing someone to imagine, develop and scale a disruptive innovation independent of traditional institutions;
- Despite the growth of America’s innovation-based economy, not every American has been brought onto the country’s innovation team.

But most important, the work of the National Commission and the report it has generated recognizes that innovation is what will grow the U.S. economy. Innovation is not a silver bullet requiring a singular action. More money, the creation of a new program or a change in leadership will not suffice. *Competing in the Next Economy* is not just the report’s title, but an acknowledgment that a new approach is needed.

To achieve greater than 3 percent annual growth in gross domestic product will require an “all-hands-on-deck” commitment by the nation’s leadership. America has tried tax cuts, and the country has spent far more than the government has taken in. Neither have achieved the results necessary to increase inclusive prosperity consistent with the Council’s mission to increase the standard of living for all Americans. Something different is required. Just as innovation is the key to growth, so must we innovate the nation’s policy agenda. Only by doing that can we achieve the goals set out by the Council and its Commission.

Is the aspirational goal of 10x innovation possible? That is, perhaps, the wrong question. **10x innovation is a way of thinking differently than what the country has tried for a generation.** The agricultural revolution, the industrial revolution, and the digital revolution upended entire sectors of the economy creating entirely new industries and services, and required entirely new skills. The new age of innovation called for in this report will be achieved when jobs are being created, wages are rising, products are being manufactured sustainably and diversity describes those engaged in the innovation ecosystem, not those left out.

Even with the release of this report, the work is not done.

The Commission will continue. Important ideas were left on the table. Critical recommendations were only hinted at and, of course, science and technology will continue to evolve and disrupt. The United States must be more nimble as a nation. Recommendations like the National Council on Innovation and Competitiveness are intended to better prepare the country and its leadership to adapt and move quickly to keep the U.S. competitive. But there will be more to do and new challenges to overcome.

Important as it is to acknowledge that others are making similar investments and have their own plans for leadership, it is equally important to acknowledge that, with certain exceptions, those efforts are out of America's control. The United States must get its own house in order and put the policies, the infrastructure, and the tools in place for its citizens and institutions to compete and thrive. Only then will the country prosper. Not because we bested someone else, but because we believed in and invested in ourselves.

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Director, Emory Biomedical Catalyst  
Emory University

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Director, Technology Deployment and Outreach  
Pacific Northwest National Laboratory

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Associate Laboratory Director for Science &  
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National Academy of Medicine

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Dean, College of Arts & Sciences  
Georgia State University

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Deputy Director—Science, Technology &  
Engineering  
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# Working Group 1

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Emory Biomedical Catalyst

**Mr. Andre Doumitt**

Director, Innovation Development  
The Aerospace Corporation

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Former Director  
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**Dr. Laurie Locascio**

Vice President for Research  
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SVP, Enterprise Innovation & 5G Solutions  
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Former Director  
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Sundt Construction

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QTS Data Centers

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Virtual Construction Application Developer  
Sundt Construction

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Head of Government Relations  
Aurora Innovation

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Executive Vice President and Chief Financial Officer  
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Gore Professor of Chemical and Biomolecular Engineering  
University of Delaware, and  
Institute Director  
National Institute for Innovation in Manufacturing Biopharmaceuticals

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Executive Associate Dean of Faculty Academic Advancement, Leadership and Inclusion, School of Medicine  
Emory University

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Going Global Ventures

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AT&T

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Senior Military Fellow  
Center for a New American Security

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Research Scientist,  
MIT Computer Science and Artificial Intelligence  
Lab & MIT Initiative on the Digital Economy  
Massachusetts Institute of Technology

**Dr. Georgia Tourassi**

Director, Health Data Sciences Institute, and  
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Professor and Director, School of Molecular  
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Enterprise  
Arizona State University

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## Exploring the Future of Sustainable Production and Consumption

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Chief Manufacturing Officer  
Oak Ridge National Laboratory

#### Ms. Stacy Lippa

Vice President of Distribution  
Five Below

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Head of Biodesign  
Lawrence Berkeley National Laboratory

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Resilience, Sustainability, and Economic Inclusion  
Emory University

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Nike

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Southern Company Gas

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Lumina Foundation

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Executive Director, Swette Center for Sustainable  
Food Systems  
Arizona State University

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Associate Laboratory Director, Energy Technologies  
Area and Division Director, Energy Storage and  
Distributed Resources Division  
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CEO  
Infinitum Humanitarian Systems

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President & CEO  
Manhattan Area Chamber of Commerce

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Harvey Endowed Professor of Marketing, and  
Co-Director, Monica Wooden Center for Supply  
Chain Management & Sustainability  
University of South Florida

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Professor, Environmental Engineering, College  
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Faculty Fellow, Kiran C. Patel Center for Global  
Solutions  
University of South Florida

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Distinguished Research Fellow, Sustainability and  
Green Chemistry  
Zymergen

#### Dr. Tensie Whelan

Clinical Professor of Business and Society, and  
Director, Center for Sustainable Business  
NYU Stern School of Business

#### Dr. Paul Wolpe

Raymond F. Schinazi Distinguished Research Chair  
in Jewish Bioethics and  
Director, Center for Ethics  
Emory University

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## Optimizing the Environment for the National Innovation System

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Vice President for Research  
Kansas State University

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Assistant Professor and Director of the Competition Advocacy Program at the Global Antitrust Institute  
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Vice President Global Networking Product Management  
Verizon Business Group

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Founder and Principal  
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Vice President for Research and Innovation Partnerships  
Northern Illinois University

#### Mr. Brad Brekke

Principal  
The Brekke Group

#### Dr. Branden Brough

Deputy Director, The Molecular Foundry  
Lawrence Berkeley National Laboratory

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Program Officer  
The Lemelson Foundation

#### Mr. Jim Carlisle

Senior Vice President, Federal Government Relations  
Bank of America

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Chief Technology Transfer Officer  
Lawrence Berkeley National Laboratory

#### Ms. Ji Mi Choi

Associate Vice President, Entrepreneurship and Innovation, Office of Knowledge Enterprise Development  
Arizona State University

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Verizon

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Executive Director, Center for Government Insights  
Deloitte

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University of Delaware

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Princeton University

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Senior Vice President, Global Strategic Networks  
Elsevier

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Partner  
K&L Gates LLP

#### Ms. Elizabeth P. Gray

Partner  
Willkie Farr & Gallagher LLP

#### Dr. Robert Kazanjian

Asa Griggs Candler Chair and Professor in Organization & Management, and Senior Associate Dean for Strategic Initiatives  
Emory University

#### Dr. Ushma Kriplani

Manager, Strategic Planning and Initiatives  
Argonne National Laboratory

#### Ms. Julie Lenzer

Chief Innovation Officer  
University of Maryland, College Park

#### Dr. Sorin Lungu

Professor, National Security Industrial Base Department, Eisenhower School of National Security and Resource Strategy  
National Defense University

#### Ms. Rebecca Macieira-Kaufmann

#### Dr. Anthony Margida

CEO  
TechGrit

#### Dr. Cheryl Martin

Founder  
Harwich Partners

#### Dr. Sunil Mithas

World Class Scholar and Professor, Muma College of Business  
University of South Florida

#### Dr. Isabelle Monlouis

Professor of Practice and Associate Director, H.J. Russell Center for Entrepreneurship, Entrepreneurship and Innovation Institute  
Georgia State University

#### Ms. Christina Orsi

Associate Vice President for Economic Development  
The University at Buffalo

#### Dr. Michael Paulus

Director, Technology Transfer  
Oak Ridge National Laboratory

#### Mr. Greg Pellegrino

Principal | Customer & Marketing Strategy  
Deloitte

#### Dr. Kenneth Poole

CEO/President  
Center for Regional Economic Competitiveness

**Ms. Irene Qualters**

Associate Laboratory Director, Simulation &  
Computation  
Los Alamos National Laboratory

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President  
University of Memphis

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Vice President of Federal Tax and Economic Policy  
The Tax Foundation

**Mr. Bruce Sommer**

Director of Economic Development and Innovation  
University of Illinois at Springfield

**Ms. Sara Sutton**

Founder and CEO  
FlexJobs

**Ms. Anne Tucker**

Professor of Law  
Georgia State University

**Dr. Rao Unnava**

Dean of the UC Davis Graduate School  
of Management  
University of California, Davis

# Working Group 4

## Unleashing Capabilities for Work and Entrepreneurship

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#### Mr. Leslie Boney

Vice Provost, and Director, Institute for Emerging Issues  
North Carolina State University

#### Dr. Lee Cheatham

Director, Technology Deployment and Outreach  
Pacific Northwest National Laboratory

#### Dr. Carol Dahl

Executive Director  
The Lemelson Foundation

#### Dr. Lloyd Jacobs

Former President  
University of Toledo

#### Ms. Julie Meier Wright

Strategic Advisor  
Collaborative Economics

#### Ms. Erica Volini

Global Human Capital Leader  
Deloitte

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#### Ms. Charlotte Alexander

WomenLead / Connie D. McDaniel Chair, and Associate Professor of Law and Analytics, J. Mack Robinson College of Business  
Georgia State University

#### Dr. Moody Altamimi

Director, Office of Research Excellence  
Oak Ridge National Laboratory

#### Dr. Carlotta Arthur

Director, The Clare Boothe Luce Program for Women in STEM  
Henry Luce Foundation

#### Dr. Sundari Baru

#### Dr. Dedric Carter

Vice Chancellor for Operations and Technology Transfer, and Professor of Engineering Practice, McKelvey School of Engineering and Applied Sciences, and U.S. Scholars Ambassador, McDonnell International Scholars Academy  
Washington University in St. Louis

#### Dr. Jasbir Dhaliwal

Executive Vice President for Research and Innovation  
University of Memphis

#### Mr. Ernest Dianastasis

Founder and CEO  
The Precisionists, Inc.

#### Mr. J.R. Edwards

Staff, Chief Technology Office/Enterprise Business Transformation, and Project Lead/Digital Futures  
Lockheed Martin

#### Dr. Jerry Haar

Professor and Executive Director for the Americas, College of Business  
Florida International University

#### Mr. Bill Johansen

Senior Advisor to the Deputy Laboratory Director for Research  
Lawrence Berkeley National Laboratory

#### Mr. Steven Kuyan

Director, Entrepreneurship Institute for Invention, Innovation, and Entrepreneurship, and Managing Director  
New York University Future Labs

#### Ms. Sara Lawrence

Program Director, Innovation Led Economic Growth  
RTI International

#### Ms. Amy Lientz

Director for Energy Industry Supply Chain  
Idaho National Laboratory

#### Mr. John Melville

Co-CEO  
Collaborative Economics

#### Ms. Esther Owolabi

Manager, Diversity, Equity, and Inclusion Talent Engagement  
Google

#### Mr. Thomas Ruhe

President and CEO  
NC IDEA

#### Mr. Luke Tate

Associate Vice President and Executive Director, Opportunity Initiatives, Office of the President  
Arizona State University

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President & CEO  
Walk West

#### Ms. Van Ton-Quinlivan

CEO  
Futuro Health

#### Mr. Terry Urbanek

International Representative  
United Association of the Plumbing and Pipefitting Industry

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President and CEO  
VentureWell Foundation

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Director of Policy Outreach  
Opportunity Insights

#### Ms. Sunne Wright McPeak

President & CEO  
California Emerging Technology Fund

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For more than three decades, the Council on Competitiveness (Council) has championed a competitiveness agenda for the United States to attract investment and talent, and spur the commercialization of new ideas.

While the players may have changed since its founding in 1986, the mission remains as vital as ever—to enhance U.S. productivity and raise the standard of living for all Americans.

The members of the Council—CEOs, university presidents, labor leaders and national lab directors—represent a powerful, nonpartisan voice that sets aside politics and seeks results. By providing real-world perspective to Washington policymakers, the Council's private sector network makes an impact on decision-making across a broad spectrum of issues from the cutting-edge of science and technology, to the democratization of innovation, to the shift from energy weakness to strength that supports the growing renaissance in U.S. manufacturing.

The Council's leadership group firmly believes that with the right policies, the strengths and potential of the U.S. economy far outweigh the current challenges the nation faces on the path to higher growth and greater opportunity for all Americans.

## **Council on Competitiveness**

900 17th Street, NW

Suite 700

Washington, D.C. 20006

+1 (202) 682-4292

[Compete.org](http://Compete.org)

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**Council on Competitiveness**

900 17th Street, NW, Suite 700, Washington, D.C. 20006, T 202 682 4292

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