Testimony of Deborah L. Wince-Smith, President and CEO
Council on Competitiveness
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Hearings on Fueling American Innovation and Recovery:
The Federal Role in Research and Development
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Chairman Yarmuth, Ranking Member Womack, and Members of the Committee, thank you for the opportunity to appear before you today to discuss the role of Federal research and development in fueling U.S. innovation and economic growth.

I have the honor and privilege of representing the Council on Competitiveness, a non-partisan leadership organization of corporate CEOs, university presidents, labor leaders, and national laboratory directors committed to advancing U.S. competitiveness in the global economy, and a rising standard of living for all Americans. Since its founding in 1986, the Council has explored the Federal government role in innovation, and advocated for measures that could generate greater returns to the Nation from its public investments in R&D.

For 75 years, the Federal government has fulfilled the vision articulated in Vannevar Bush's seminal report *Science: The Endless Frontier*, sowing seeds for the innovation and technology-driven productivity gains that propelled the United States to global economic and geopolitical leadership, generated unprecedented wealth for Americans, and drove social progress. However, two decades into the 21st century, the global environment for leveraging science and technology for economic gain and social benefit has fundamentally changed, as laid out in the Council's *2018 Clarion Call for Competitiveness*.

The United States Faces New Competitive Realities

The United States now competes in a multi-polar science and technology world. In 1960, the United States dominated global R&D, accounting for an estimated 69 percent share.[1] The United States could drive developments in technology globally by virtue of the size of its investment. But, as other nations have increased their R&D investments and capacity for innovation, the U.S. share of global R&D spending has dropped to 28 percent in 2018, and China, for example, has risen to account for 26 percent.[2] This has diminished the U.S. dominance and leverage over the direction of technology advancement. U.S. R&D investment as a percent of GDP ranks 10th in the world, behind major U.S. competitors such as Korea, Taiwan, Japan, and Germany.[3]

[1] Effective Partnering: A Report to Congress on Federal Technology Partnerships, U.S. Department of Commerce, Office of Technology Policy, 1996.
[2] Main Science and Technology Indicators, OECD.
[3] Ibid.

Disruptive technologies are reshaping the economy and society. Humanity stands in the midst of the greatest revolutions in science and technology—biotechnology and gene-editing, nanotechnology, artificial intelligence, autonomous systems, and a new phase of the digital revolution characterized by vast deployment of sensors, the Internet of Things, and the big data tsunami. Each of these technologies is revolutionary and game-changing in its own right. But they are now colliding and converging on the global economy and society simultaneously, with profound implications for U.S. economic and national security.

Of these technologies, several are expected to transform nearly all aspects of human endeavors—on a scale much like electricity enabled widespread industrialization and the production of a vast array of goods and services; provided the power for the rise of cities, deployment of mass communications and modern transportation systems; and propelled a leap in human productivity.

Digital technologies are now fundamentally integrated into every aspect of human existence, society, and activity—defense, the economy, every industry, heath care, the research enterprise, education, communications, critical infrastructure, transportation, personal living, and more. The function of the United States and its society are now totally dependent on these technologies. One needs only consider the role digital technologies have played in 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 tele-health—helping prevent the total collapse of the economy and maintain social functioning.

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. The study also suggests that 45 percent of the world's current disease burden could be addressed with science conceivable today.[4]

Artificial intelligence is likely to be the defining apex technology of the next 50 years—expected to drive a massive transformation in: all aspects of global commerce and business operations, military systems, health care, education, R&D, 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 technologies are merging the physical and virtual worlds, AI will make them intelligent.

These technologies will shape the global economy for decades to come. They are disrupting industries around the globe, and altering the patterns of society and 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.

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

Continued leadership in these technologies 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.

China has set its sights on world technology leadership, presenting a growing strategic competitive challenge to the United States. It has launched a full force, richly funded, licit and illicit campaign to achieve this goal. China's investment in R&D reached $554 billion in 2018, second only to the U.S. investment of $581 billion.[5] Its dramatic annual rate of R&D growth has it on a path to soon become the world's largest R&D performer. 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.[6] It has overtaken the United States in science and engineering publications,[7] and now lags only the United States in international patents filed.[8]

China is pursing aggressive plans for every strategic critical technology, backed by hundreds of billions of dollars in investment. It is deploying a multi-pronged strategy to acquire technologies and intellectual property from other countries by both licit and illicit means. This includes building research centers in U.S. innovation hubs, forming partnerships with U.S. research universities and companies, forcing joint ventures for market access, sending students to the United States for academic studies, and pursuing top scientists and engineers globally through well-funded talent recruitment programs. To absorb foreign intellectual property and technology, Chinese authorities have established engineering research centers, enterprise-based technology centers, state laboratories, technology transfer centers, and high-technology service centers.[9]

Believing that the nation the leads in AI will shape a global transformation of the economy, society, human activity, and national security, China's *New Generation of Artificial Intelligence Development Plan* is breathtaking in its scope and ambition, a blueprint for constructing an AI innovation ecosystem that they believe will make China the world's AI leader by 2030. Most striking, they have laid out a vision for deploying AI across nearly all elements of society, and a detailed plan for building and acquiring specific AI technology capabilities.

China is by no means the only country that recognizes technology as the main driver of economic growth and productivity. Many smaller, often overlooked nations have distinctive strategies to build global innovation competency and competitiveness. These 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.

These new competitive realities have profound implications for the United States. Our leadership in technology and innovation is under threat, and we face a period of rapid technological change and economic turbulence. The reorganization of the economy around powerful technologies is inherently disruptive, creating and destroying businesses, markets,

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[5]Gross Domestic Expenditure on R&D, OECD Main Science and Technology Indicators.
[6] National Center for Science and Engineering Statistics, National Science Foundation.
[7] The State of U.S. Science and Engineering 2020, National Science Foundation.
[8] Patent Cooperation Treaty Yearly Review 2019, World Intellectual Property Organization.
[9] Foreign Intellectual Property and Technology, Office of the U.S. Trade Representative.

and jobs—as so illustrated by the digital revolution. The impact will be felt across numerous dimensions—economic, employment, and social and community stability; and portions of the U.S. workforce are at risk of displacement, which would result in greater economic inequality.

National Commission on Innovation and Competitiveness Frontiers

What should the United States do to confront these new competitive realities, and safeguard, strengthen, and make the most productive use of our innovation capacity? To answer this question, the Council has convened a high-level National Commission on Innovation and Competitiveness Frontiers, comprised of more than 60 CEOs, university presidents, leaders from our labor community and national laboratory enterprise, chief science and technology officers, and other top executives - as well as a larger community of innovation stakeholders from across the country. As a Commission Co-Chair, I am honored to work with my fellow Co-Chairs: Dr. Mehmood Khan, Chief Executive Officer, Life Biosciences, Inc., and Chairman, Council on Competitiveness; Mr. Brian Moynihan, Chairman and CEO, Bank of America, and Industry Vice Chair, Council on Competitiveness; Dr. Michael Crow, President, Arizona State University, and University Vice Chair, Council on Competitiveness; and Mr. Lonnie R. Stephenson, International President, International Brotherhood of Electrical Workers, and Labor Vice Chair, Council on Competitiveness.

The Commission is a multi-year national effort initially examining challenges and opportunities, and developing a national action agenda in three key core topics at the heart of long-term innovation and competitiveness: developing and deploying at scale disruptive technologies; exploring the future of sustainable production and consumption, and work; and optimizing the environment for the national innovation system.

Over just the past few months, hundreds of experts from our Commission community convened in a major launch conference at Arizona State University and met virtually in nearly 50 on-line working group sessions focused on these core topics. Out of this conference and these dialogues, nine priorities or "pillars" were identified as:

- **Urgent:** Failure to act could create serious, even dangerous consequences for the United States, and the world.
- **Strategic:** They are fundamental to U.S. economic security, and U.S. national security and military strength.
- **Pivotal:** They play a prime and determining role in the scope and rate of U.S. innovation.

Five of these priorities are directly linked to the Federal role in research and development. Working groups are delving deeper, and developing recommendations this summer and fall to address them:

Securing Capabilities in Strategic/Critical Technologies. The fundamental role of emerging technologies in shaping the economy, solving societal challenges, and securing military capabilities and homeland defense, and the private sector's primary role in advancing these technologies, are erasing the boundary between national security and economic security. 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, AI, and autonomous systems such as robotic equipment and drones in its operations—all being driven by advances in the commercial sector. For example, while DARPA and the Department of Defense invented many of the seminal AI algorithms, big technology companies such as Google, Amazon, Microsoft, and Facebook have combined these with big data and sophisticated computational infrastructure to become leaders in machine learning. The U.S. energy sector and other segments of U.S. critical infrastructure have become digitalized, and rely on commercial technology advancements. At the same time, strategic U.S. competitors have escalated their efforts in critical technologies to boost both their commercial competitiveness and military capabilities. This tightening symbiosis between national and commercial interests is creating the need for greater integration, coordination, and optimization of U.S. investment in research and technology development.

It is important to note that 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 technological ambition during the U.S. space program—to 0.62 percent of GDP in 2018.[10] This is lower than the U.K., Korea, Germany, Russia, and several other U.S. competitors.[11] If today's Federal R&D investment as a percent of GDP matched this 1964 height, the investment would be $400 billion, but was about $130 billion in 2018.[12] In constant dollars, after the American Recovery and Reinvestment Act spending, total Federal R&D spending has been on a decline, from about $130 billion in 2010-2011 to $115 billion in 2018.[13]

Contributing to the advancement of critical technologies are numerous research and technology development centers across the United States, operated or supported by the Federal government. They include the 17 laboratories in the crown jewel Department of Energy National Laboratory System, which house scientific instrumentation and research facilities available to the public and private sector. These innovation assets also include 14 diverse national manufacturing innovation institutes, public-private partnerships jointly funded by government and private industry.

Unfortunately, at some of these premier and globally unique laboratories and facilities, 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 and repair hamstrung by chronic underfunding.[14]

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[10] National Patterns of R&D Resources: 2017-18 Data Update, Table 1, National Science Foundation.
[11] Main Science and Technology Indicators, OECD.
[12] National Patterns of R&D Resources: 2017-18 Data Update, Table 6, National Science Foundation; Budget of the United States, Historical Tables, Table 10.2.
[13] National Patterns of R&D Resources: 2017-18 Data Update, Table 6, National Science Foundation.
[14] 2018 Clarion Call, Council on Competitiveness, pp. 7-9.

Strengthening U.S. Resiliency. The COVID-19 crisis and virus economy have exposed key U.S. weaknesses such as fragile supply chains that cracked under stress, lack of control over some supply chains that provide critical supplies to the United States, reliance on China for critical U.S. needs, production inflexibility in the face of sudden surging demand, and no national plan for coordinating Federal and university COVID-19 research. Rather than preparing society and its systems for specific disruption or disaster scenarios, for which there are many, the Council on Competitiveness has long advocated for building the processes, well-trained people, and robust systems that provide the ability to limit the impact and bounce back rapidly from whatever disruption or disaster occurs.[15] The Commission's working groups are taking a close look at resiliency, particularly supply chain issues. However, the Federal government could play a role in advancing technologies such as biotechnology, digital technologies, advanced materials, and autonomous systems which have numerous potential applications that can contribute to building a broad capacity for resiliency at every level of our society and its systems.

Bridging the Valley of Death. The so-called "valley of death" is viewed as a major bottleneck in the U.S. innovation system—an innovation rate limiting step—preventing many potentially valuable innovations from reaching the marketplace or slowing their progress toward commercialization, and barring 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. Bridging the valley of death is one of the highest priorities in raising the rate of U.S. innovation.

The valley of death is reached when start-ups and other companies do not have 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 innovations arise in the start-up sector, and when they are transferred or "spin-out" from universities into the private sector for application and commercialization. The Federal government, national laboratories, and universities often support research and technology development up to this critical juncture in the innovation life cycle.

Companies that move through the 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. When the capital level required is large, manufacturing frequently is scaled off-shore, and the United States loses substantial returns on its investment in research and development.

To capture the full fruits of the U.S. innovation ecosystem, the United States must bridge both gaps. The Federal government has instituted a few initiatives to help bridge this gap. This includes supporting the Manufacturing USA institutes, and some Federal departments have extended Small Business Innovation Research program funding further into the development life-cycle. Expanding testing infrastructure and test beds where innovators can test,

[15] Transform, The Resilient Economy: Integrating Competitiveness and Security, Council on Competitiveness, 2007.

demonstrate, and validate their technologies would be an additional approach as called for in the bi-partisan Endless Frontier Act.

Amplifying University and National Laboratory Technology Transfer, Commercialization, and Industry Engagements. Universities receive $37 billion in Federal R&D funding.[16] And, increasingly, technology breakthroughs come from universities and start-ups which may have spun-out of university research. For example, universities are driving many of the developments in gene-editing, while software start-ups are driving many of the developments in AI. As companies are moving away from exploratory research toward nearer-term applied R&D that supports business units, they more frequently look outside of the firm for breakthrough innovations. 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.[17] 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—as well as from national laboratories—with some exceptions, they have underperformed. The technology transfer mission has not penetrated the core of their culture, and often is not treated as a priority. In universities, faculty incentives skew in other directions.

In addition, our crown jewel national laboratories are hamstrung by Federal policies, and a lack of resources both to fulfill their missions and to optimize their contribution in support of U.S. industry and innovators seeking access to a shared national innovation infrastructure. The national laboratories turn away hundreds of promising start-ups and innovators every year due to these constraints and authorization concerns. These laboratories are positioned to play a critical role in future U.S. competitiveness, and need broad support and resources to engage more with U.S. industry.

Industry is market driven, while researchers in universities tend to focus on advancing knowledge and those in national laboratories focus primarily on advancing government missions. Time horizons are often incompatible as the private sector is driven by the fast pace of innovation. Academic researchers want to publish results, and national labs pursue longer-term mission-related developments, while industry wants to keep results proprietary for competitive advantage. Private sector innovation is increasingly multidisciplinary, yet university research remains overwhelming dominated by single discipline, investigator-driven research projects, and reward systems, publication practices, and career paths reinforce that approach. In working with universities, there may be significant intellectual property barriers.

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[16] National Patterns of R&D Resources: 2017-18 Data Update, Table 2, National Science Foundation.
[17] 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.

Some have suggested that universities partner more with industry in problem-, challenge-, and opportunity-centered research initiatives and projects. As many emerging technologies are multidisciplinary, and problems and challenges multi-dimensional, these partnerships would focus knowledge and skills from multiple disciplines on solutions and leveraging opportunities. Since such work would have 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. For example, the national laboratories' recent work to help support burgeoning industry efforts in advanced manufacturing, transportation, and materials research—through the High Performance Computing for Energy Innovation Initiative at Lawrence Livermore National Laboratory—seek to build deeper, more impactful engagement attuned to industry needs.

Creating a Diverse and Inclusive U.S. Innovation Ecosystem. The Federal government plays a key role in the diversity and inclusiveness of the U.S. innovation ecosystem through its investments in R&D and STEM education. However, at a time when it is imperative that we expand the scope and rate of U.S. innovation, many communities and U.S. citizens are disconnected from the U.S. innovation ecosystem. U.S. R&D is concentrated in certain U.S. states. Ten states account for two-thirds of U.S. R&D spending, and the top 20 states account for 86 percent of the total.[18] U.S. hubs of innovation and high-technology are largely concentrated on the U.S. coasts. Venture capital investment is highly concentrated in certain geographic regions of the United States—particularly California, New York, and Massachusetts which, together, accounted for 73 percent of venture dollars invested in 2019.[19]

Among students from racial and ethnic underrepresented groups who earn bachelor's degrees, there are a number of science and engineering disciplines in which they earn them at rates comparable to white students. However, black, Hispanic, and American Indian/Alaskan Native students graduate from high school and college at lower rates than white and Asian students, and have less engagement in the prerequisite classes needed to pursue a science or engineering degree, creating a relatively smaller pool of these students in college who could pursue STEM studies and degrees. This points to the need to increase the college-going population among these underrepresented groups and to better prepare them in the prerequisites needed for STEM studies.

As a result, technology- and innovation-driven economic opportunity is not spreading to all Americans and to all parts of the country.

The National Commission plans to release its first set of recommendations at the Council on Competitiveness 2020 National Competitiveness Forum in December.

In closing, in confronting these new competitive realities, the United States has significant competitive advantages:

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[18] U.S. R&D Expenditures, By State, Performing Sector, and Source of Funds: 2017, National Science Foundation.
[19] National Venture Capital Association 2020 Yearbook.

- We remain the world's epicenter for disruptive innovation, thanks to our exceptional research infrastructure, and low barriers to entrepreneurs and start-ups.

- We remain the world's largest investor in R&D, spending $580 billion on R&D,[20] building up a globally unparalleled national stock of science and technology.

- We have unique assets such as our national laboratory system and top research universities.

- We have a superb innovation ecosystem where industry, start-ups, labs, and universities collaborate.

- We stand at the top in terms of patents filed by all countries.

- We have a strong flow of venture capital pouring in to commercialize advanced technologies.

Nonetheless, if the United States does not make needed investments in its future, increase its scope and rate of innovation, its 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 its geopolitical leadership will be at increasing risk.

I am trained as an archeologist. Around the world and through the millennia—the creation, mastery and use of new knowledge and technology have always been the drivers and determinants of which cultures, societies, countries and economies flourished; had military advantage; gained geopolitical power; and changed the course of history. Will that be the United States in the 21st century?

[20] U.S. R&D Increased by $32 Billion in 2017, to $548 Billion; Estimate for 2018 Indicates a Further Rise to $580 Billion, InfoBrief, National Science Foundation, January 8, 2020.