TECHNOLOGY LEADERSHIP & STRATEGY INITIATIVE 15TH ANNIVERSARY – CALL TO ACTION: A COMPACT FOR ECONOMIC AND NATIONAL SECURITY

EXECUTIVE SUMMARY & THE CALL TO ACTION

Fifteen years ago, Council on Competitiveness leadership assessed while its pathbreaking "National Innovation Initiative, 2003-2005" had identified and addressed significant shifts taking place in the Nation and around the world that would shape America's innovation capacity and capabilities, they had sorely underestimated the pace of change unfurling around the world at the turn of the century.

Council leaders quickly faced in the early 2000s a churning, evolving, increasingly global technology landscape that called for a broader, more strategic effort to develop policies and actions to optimize America for a future in which innovation would be key to competitiveness.

To characterize that turbulent and transforming landscape, and to develop an action agenda to ensure U.S. technology leadership into the future, the Council launched in 2009 the Technology Leadership & Strategy Initiative (TLSI), shepherded by its founding co-chairs: Dr. Ray O. Johnson and Dr. Mark M. Little (at the time and respectively, Senior Vice President and Chief Technology Officer for Lockheed Martin, and Senior Vice President and Director of GE Global Research for the General Electric Company).

The TLSI assembled nearly 50 of the Nation's Chief Technology Officers from industry, academia, and national laboratories to meet in progressive dialogues and serve as an internal "think tank" at the Council to assess the 21st century technology landscape, explore the frontiers of emerging technologies that could bolster America's competitive edge, identify barriers that slow or prevent U.S. innovation, and design a policy strategy that maximizes America's ability to leverage new technology for national security and economic competitiveness.

Since the founding of the TLSI 15 years ago, there have been dramatic changes in the technology landscape, global competition, the U.S. innovation system, and the role of government in research, technology development, and commercialization. Over the course of these years and as these changes unfolded, the TLSI convened 29 Dialogues to conduct new analyses, address potential economic and national security impacts of technologies emerging on the horizon, identify new opportunities for American innovation, and consider solutions to new problems and challenges these developments present.

But, in the past decade, the technology landscape has shifted even more radically along numerous dimensions; change is accelerating to unprecedented speed; and the United States is facing its strongest challenger ever in the technology arena. These disruptive changes have brought about a powerful duality—the promise of heretofore unimaginable opportunity, but they also have shaken and threatened the world order.

TLSI Dialogues, 2023-2024

- #27 - June 29, 2023 @ Lockheed Martin Advanced Technology Center
- #28 - September 21, 2023 @ Lawrence Livermore National Laboratory
- #29 - February 26, 2024 @ Arizona State University

Over the past year, the TLSI convened three Dialogues under the leadership of its current co-chairs: Dr. Patricia Falcone, Deputy Director, Science and Technology at Lawrence Livermore National Laboratory; Dr. Sally Morton, Executive Vice President, ASU Knowledge Enterprise, Arizona State University; and Dr. Steven Walker, Vice President and Chief Technology Officer, Lockheed Martin. Participating CTOs and technology experts from technology-intensive industry sectors, universities, national laboratories, and the Federal government considered the unprecedented speed and scale of today's technological change and the effects on the U.S. innovation system in the creation of a 15th anniversary Call to Action – to provide an incoming administration and Congressional leaders with policy and action priorities for the coming decade.

Major themes explored in the Dialogues included the changes and challenges reshaping the U.S. defense industrial base, developing an adaptive and agile industrial base to meet U.S. economic and national security needs, changing the culture of research and innovation ecosystems, enhancing the innovation workforce in critical technologies and industries, building innovation ecosystems through national domestic strategies.

This Call to Action reflects their findings and recommendations on what the United States must do urgently and soon to ensure its continued national and economic security, geopolitical leadership, and future prosperity for its people in a world in which technology-based innovation has taken center stage in each of these domains and in which transformational change is accelerating. It proposes a framework for collaboration among government, industry, universities, and U.S. allies to advance and ensure mutual security interests.

A Call to Action: Compact for Economic and National Security Framework for Collaboration and Ensuring Mutual Security Interests	
U.S. leaders must put forth a new narrative on the primacy of technology in the national interest. ☐ In an age defined by rapid technological advancement, the ability to win future economic competitions, defend free societies, and lead globally depends on innovating with speed and scale. **Across the U.S. R&D enterprise, emphasize the importance of use-inspired research to meet economic and national security needs.** ☐ The prevalent siloed model of techno-industrial policy may need to change with the emergence of dual-use technologies and a broader view of technology and innovation in the national interest. **The United States should expand investment, encourage multidisciplinary research collaboration, and foster innovation ecosystems in areas of technology convergence.** ☐ The convergence of AI with other enabling technologies holds significant potential for opening a new age of discovery and innovation frontiers, creating significant economic benefits, strengthening national security, and driving productivity gains. **Expand investment and activities focused on rapid scaling of critical technologies. This will require engagement with players and institutions beyond the research and technology community.** ☐ Use pilots and demonstrations to move technologies more quickly toward deployment at scale. ☐ In pre-competitive consortia focus on critical technologies and engage downstream players needed for commercialization and deployment at scale. ☐ The Federal government should assess potential regulatory impacts at the conclusion of key research and technology development projects in order to reduce non-value add regulations. ☐ Short of reducing regulations, establish a corps of Tech Reg Sherpas to help small companies with innovative technologies navigate the regulatory system.	**Ramp-up engagement, develop new pathways and interfaces, and reduce the transfer time gap to move new technology faster from developers in universities and national laboratories to users across industry.** ☐ Marquee Federal research sponsors should place greater emphasis on working with industry, technology translation, and commercialization as a priority for gaining R&D awards. ☐ The Federal government—in partnership with industry, researchers, and others—should identify the highest pressing economic, national security, societal, sustainability, and government mission problems or needs. The Federal government and other institutional leaders should mobilize a community to solve a problem or need, and align R&D and program investment. ☐ Expand cooperative extension for research and technology translation across other industry sectors and user communities. ☐ Devote a small percentage of funds in each Federal research grant to technology transfer activities. ☐ Launch an education campaign directed at small businesses, start-ups, university researchers, and students to raise awareness of threats to intellectual property. **Elevate the imperative of U.S. leadership in standards development given the duality of advanced and emerging technologies in economic and national security.** ☐ Forge a new compact for a pro-active standards-setting process that reinforces the primacy of private sector leadership, strengthens U.S. engagement and elevates U.S. firms' seat at the table in global standards setting bodies. **With intertwining of economic and national security, elevate the focus on research security and the need for stronger research security plans.** ☐ NEED RECOMMENDATION ☐ Develop clearer rules and guidelines for partnerships, especially around intellectual property and data management.

Reimagine the industrial base developing dual use technologies and serving national security.

- The Department of Defense should catalyze a new innovation ecosystem to meet national security needs by opening competition to more players, and integrating and leveraging the different capabilities and skill sets of commercial firms, defense primes, universities, and the venture capital community.
- National laboratories should serve as conveners of pre-competitive consortia and research initiatives, bringing together industry, defense, commercial sectors, and universities for collaborative research.
- The Department of Defense should consider procurement requirements that stress the importance of a defense contractor's partnership with a commercial entity.
- The Federal government should increase its emphasis on advanced technologies with the potential for large benefits or delivering game-changing capabilities rather than the least risky or least expensive technology option.
- The Department of Defense should rationalize, streamline, and adequately fund its organizations and programs that serve as gateways to the defense market for commercial firms of all sizes.
- The Department of Defense should articulate clear pathways and provide support for small businesses advancing their defense-funded innovations to TRL-5 and above.
- Establish secure facilities for interactions between universities, companies, and the Department of Defense.
- Offer training in research security to small businesses and start-ups engaging with the DoD, and among researchers and students at universities.
- Launch an education campaign directed at small businesses, start-ups, university researchers, and students to raise awareness of threats to intellectual property. Train student researchers on private sector requirements for managing and protecting intellectual property and data.

Build and bolster innovation capacity and capability across the Nation by fostering and expanding place-based and place-making innovation beyond the high-tech superstars on the U.S. coasts.

- State and local governments should increase resourcing of state and regional innovation efforts.
- Communities should foster the co-location of innovation assets, for example, by building innovation districts.
- Regions should consider cost-sharing investments to establish large-scale or expensive infrastructure shared by universities and their industry partners.
- Universities and state and local political leaders should offer compelling narratives about the importance of R&D and its commercialization to the state, local and regional economy, industrial base, jobs, and national security.
- Develop models to coordinate where appropriate the efforts of the major innovation hubs supported by Federal investments, to better leverage them for both economic and national security, and develop clear pathways to transition innovations into production.
- Ensure skills scale in tandem with scaling of new technologies. Across the Nation, reestablish skilled trade, vocational, and technical education programs and programming for the modern technology era.

Engage U.S. allies to expedite the research, development, and scaling of technologies critical for economic security and joint security.

- Identify specific technology and scientific areas in which collaboration would benefit the United States and its allies, where allies have leading edge specializations, and where allies need to build capacity.

For more details on these recommendations, see the full Call to Action later in this report.

INTRODUCTION

Fifteen years ago, Council on Competitiveness leadership assessed that while its pathbreaking "National Innovation Initiative, 2003-2005," had identified and addressed significant shifts taking place in the nation and around the world that would shape America's innovation capacity and capabilities, they had sorely underestimated the pace of change unfurling around the world at the turn of the century.

Council leaders quickly faced in the early 2000s an evolving, increasingly global technology landscape that called for a broader, more strategic effort to develop policies and actions to optimize America for a future in which innovation would be key.

To characterize that turbulent and transforming landscape, and to develop an action agenda to ensure U.S. technology leadership into the future, the Council launched in 2009 the **Technology Leadership & Strategy Initiative (TLSI)**, shepherded by its founding co-chairs: Dr. Ray O Johnson and Dr. Mark M. Little (at the time and respectively, Senior Vice President and Chief Technology Officer for Lockheed Martin, and Senior Vice President and Director of GE Global Research for the General Electric Company).

The Council and the founding co-chairs established the TLSI with the following goals:

- Identify critical technology and policy roadmaps to ensure that the United States sustains the innovation and technology advantage required for national security and economic competitiveness.
- Convene technology leaders from America's premier companies, universities, and laboratories to understand technology investment drivers and strategies.

TLSI Leadership

Current Co-Chairs:

Dr. Patricia Falcone
Deputy Director for Science and Technology
Lawrence Livermore National Laboratory

Dr. Sally C. Morton
Executive Vice President of Knowledge Enterprise
Arizona State University

Dr. Steve Walker
Vice President & Chief Technology Officer
Lockheed Martin

Chair Emeriti:

Dr. Jahmy Hindman
Chief Technology Officer, John Deere

Dr. Keoki Jackson
Senior Vice President, MITRE National Security
(former CTO, Lockheed Martin)

Dr. Greg Hyslop
Chief Engineer Emeritus, Boeing

Dr. John J. Tracy
Retired Chief Technology Officer and Senior Vice President, Engineering, Operations & Technology, Boeing

Dr. Klaus G. Hoehn
Retired Vice President, Advanced Technology and Engineering, Deere & Company

Dr. Mark M. Little
Retired Senior Vice President and Chief Technology Officer, General Electric Company, and Former Director, GE Global Research

Dr. Ray O Johnson
Operating Partner, Bessemer Venture Partners
(Retired Senior Vice President and Chief Technology Officer, Lockheed Martin)

- Establish a new paradigm for collaboration between the public and private sectors to optimize America's investments in research, talent, and technology.

To work toward meeting these goals, the TLSI assembled nearly 50 of the Nation's Chief Technology Officers from industry, academia, and national laboratories to meet in progressive dialogues and to serve as an internal "think tank" at the Council to:

- Map the technology landscape of the 21st century global economy.
- Chart the most promising "frontiers" of technology and sources of competitive advantage in the 21st century.
- Benchmark technological capacity and deployment in the United States and globally.
- Identify barriers to being a first mover toward frontier technologies.
- Identify barriers to more effective partnerships with the Federal government.
- Design a policy strategy to leverage public and private sector technology investments more effectively and collaboratively.
- Accelerate technology deployment and value creation in the United States.

And to prime the pump for the TLSI's early efforts, the Council struck a strategic partnership with the Department of Defense, spanning multiple administrations, to help the Department improve its connectivity to the private sector innovation engine. The Department recognized its future depended on greater osmosis: increasing the flow into the Pentagon of ideas, technologies, and innovations from companies, large and small, and on commercial terms; as well on as opening the aperture on how it could collaborate better with academia. Over the TLSI's 15-year history, Department of Defense technology leaders, defense primes, and companies that develop defense technology and serve national security-related missions have participated in the TLSI.

Over the course of 15 years, the Council has convened 29 TLSI Dialogues, each addressing contemporary and emerging issues, challenges, and opportunities shaping the U.S. innovation ecosystem.

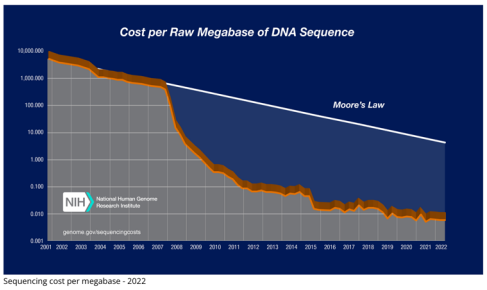
REVOLUTION IN THE TECHNOLOGY LANDSCAPE & EVOLUTION OF THE TLSI DIALOGUES

Since the founding of the Council on Competitiveness Technology Leadership and Strategy Initiative 15 years ago, there have been dramatic changes in the technology landscape, global competition, the U.S. innovation system, and the role of government in research, technology development, and commercialization. With these radical transformations, the TLSI evolved along with them, conducting new analyses, addressing potential economic and national security impacts of technologies emerging on the horizon, identifying new opportunities for American innovation, and considering solutions to new problems and challenges these developments present.

TLSI, The Early Years, 2009-2015

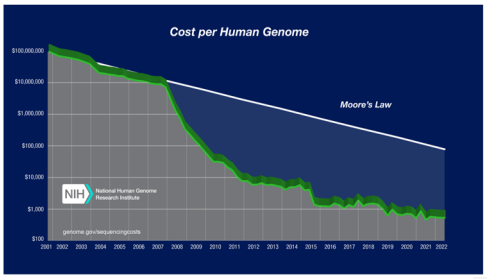
Technology Landscape:

The digital revolution entered a new phase. In the first few years after TLSI was founded, touchscreen devices and smart phones began to scale, paving the way for an era of mobile computing and a vast world of millions of apps that support human activity in every dimension of life. The app-enabled ride-hailing service Uber was founded and upended an industry, and Twitter began to scale. By September 2009, about one year after Apple opened is iTunes App Store, two billion apps had been downloaded.[1] Social media began a rapid scaling and Facebook went global, doubling its user base over a year from 150 million to 350 million users. Streaming TV began its march to scale, and the first cryptocurrency—Bitcoin—was introduced. The Internet of Things began to grow rapidly, and AR/VR use was increasing in business and the gaming world.



Sequencing cost per megabase - 2022

The biotech revolution reached a pivotal moment. In the few years just prior to the founding of TLSI, the cost of genetic sequencing took a nosedive, fueling the biotech revolution and intensifying genomic research. In 2010, scientists created the first synthetic organism. In 2012, a radical breakthrough in biotech occurred—the discovery of CRISPR-Cas 9—providing the power to cut and paste bits of DNA wherever they are wanted, theoretically, into the genome of any living thing,



[1] The Top 10 Tech Trends of 2009, CNN, December 22, 2009.

with a previously unimaginable level of precision and efficiency. Its potential applications include development of new medical diagnostic tests and targeted treatments for medical conditions, new industrial products, stronger and disease resistant crops, new biofuels, and more.

A new Space Age began. In 2015, SpaceX successfully launched the first reusable rocket, opening the door to a new era of space exploration and commercial space.

The Federal government took a leap downstream in the innovation process. The Federal government's role in technology development had largely been limited to basic research – some applied – and developing technology for government missions. But, for example, the 2009 stimulus—the American Recovery and Reinvestment Act—appropriated billions of dollars to accelerate the development and deployment of renewable energy. This included $2 billion to establish advanced battery manufacturing facilities. Other funding supported large grants to build pilot, demonstration, and commercial scale biorefineries.

The Federal government targeted specific areas of technology for R&D. While the Federal government had been cautious about "picking winners and losers," it began targeting specific areas of technology for R&D. These included advanced manufacturing, cyber-physical systems, flexible manufacturing, foundations for the bioeconomy, nanotechnology, bioinformatics, cybersecurity, and clean energy technologies.

The Federal government prioritized new approaches to innovation. Agencies were called to pursue solutions to the Nation's practical challenges with high-risk, high-return research and grand challenges. Agencies were urged to evaluate new approaches to support multidisciplinary research, such as the convergence of bio-, info-, and nanotechnologies; and to accelerate technology commercialization and innovation, including incentive prizes, university-industry partnerships, proof-of-concept centers, and regional innovation clusters. For example, the Department of Energy convened industry and academic experts to explore R&D challenges in renewable energy and energy efficiency, identifying R&D priorities, setting outcome goals, developing roadmaps, developing multi-year research plans, and investing in competitively selected projects with industry, universities, and partnerships to meet outcome goals.

Manufacturing rose on the national innovation agenda. In 2014, Congress passed the Revitalize American Manufacturing and Innovation Act, authorizing the U.S. Department of Commerce to hold competitions for manufacturing innovation institutes on topics of highest importance to industry. By 2023, 17 ManufacturingUSA institutes had been established.

The TLSI Agenda:

As a foundational step, the Council on Competitiveness conducted a nationwide CTO survey of Council with R&D Magazine, to learn about how U.S.-based CTOs and R&D directors think about their companies, the state of U.S. research, and how they measure innovation and success. Most important, the survey examined what kinds of environments and what factors are critical for spurring innovation in the future.

- Eighty-five percent of respondents at the time felt the United States was the current leader in R&D, but only 36 percent believed that would be the case in five years under current trends.
- Outside the United States, respondents believed the EU would be the greatest source of research and innovation in the next five years, followed by China, Japan, and India.
- Talent and investment in research were identified as most crucial to innovation performance. Ninety percent of the CTOs ranked education and skills as a top-5 factor in the growth of competitiveness overseas—with 34 percent ranking it No. 1.

Factor	CTOs Ranking this a Top-5 Factor	CTOs Ranking this as the No. 1 Factor
Education and Skills	90%	34%
Public R&D Investment	76%	26%
University/Lab Infrastructure	74%	17%
Economic Stability	63%	13%
Public Policy–IP, Tax, Regulations	55%	3%

The early years of TLSI progressive dialogues addressed several major emerging issues and cutting-edge themes:

Globalization of R&D. TLSI dialogues explored the impact and implications of the globalization of R&D, rising R&D capabilities overseas, the global dispersion of innovation, and how firms are tapping teams around the world. Concerns were raised about intellectual property protection, data security, and loss of control over operations. Government officials often struggled to stay abreast of technology progress outside U.S. borders, and to draw a balance between the need to collaborate overseas and their government missions, particularly in national and homeland security.

Talent. This included the need to educate and train Americans, attract and retain overseas talent, math and science education, and entrepreneurial and trade skills essential to 21st century commercialization.

Multidisciplinarity. More disciplines needed to be attuned to innovation opportunities, and more multidisciplinary approaches to research were needed, as solving big challenges requires multiple disciplines. The policy implications are wide ranging, and dialogue participants raised issues such as: higher-education curricula, training for workers to operate effectively in teams, research budgets and university programs that allow for collaboration across silos, organizing more research dollars around particular challenges than in disciplinary buckets, and ensuring a more balanced Federal research portfolio across health, physical, and social sciences.

Business environment for innovation. A range of regulatory, legal, and policy issues, as well as features of the U.S. research system, impeded deployment of new knowledge and technologies, and created barriers to rapid innovation. These included liability risk as a barrier to introducing new technologies, pressure from financial markets that make it difficult for businesses to take on longer term projects, challenges small business and start-ups face accessing venture capital, ITAR regulations that restrict U.S. technology from selling worldwide, limits on the use of defense innovations in

commercial products and services, and difficulties accessing top global talent. Game-changing enabling technologies may require new approaches to regulation, while intellectual property and technology transfer laws and practices created significant barriers to industry-university collaboration. Dialogue participants noted that many universities employ master agreements that are "one-size-fits-all," despite vast differences in the market realities of different industries. Company-university collaboration also suffered, said some, from current laws that incentivize universities to pursue more rigid profit-making IP strategies than would be best for commercialization. This concern extended to industry working with the Nation's national laboratories. Dialogue participants called for reforms in areas such as export controls, taxes, intellectual property, technology transfer, immigration, litigation, and patents.

High priority technologies and projects. Nanotechnology and biotechnology were seen as high priority emerging and interdisciplinary fields. TLSI participants identified mega projects to address 21st century national grand challenges and goals as an area for greater exploration. These included challenges such as global pandemic risk, food and water supplies, energy, terrorism, climate risks, cyber security, critical materials, and managing massive data flows. Modeling and simulation with high performance computing was seen as a way to accelerate and multiply U.S. innovation, but there were very few users.

At the end of this first few years of work, TLSI had generated several positive outcomes for U.S. technology leadership:

- Ignited a robust national conversation, and identified policies and practices that would improve the speed and volume of technologies that move from lab to market, including technologies used to achieve government missions.
- Built a powerful coalition of the Nation's top technology leaders to urge and take action, as well as identify future technology and policy priorities.
- Identified several grand challenges and strategic technologies that would help solve them, providing the Nation with an improved technology roadmap.
- Contributed directly or indirectly to policy reform efforts underway by the Administration or Congress on topics such as intellectual property, export controls, basic research, community colleges, manufacturing, immigration, STEM education, and high performance computing. The TLSI's engagement with the Department of Energy played a direct role in the department's effort to boost corporate collaboration with the national laboratories.
- By bringing together top technology leaders, the TLSI also spurred new relationships and collaborations between government, industry, academia and the national laboratories.
- Insights from TLSI dialogues and reports have been carried by TLSI participants to other coalitions and advisory bodies to the nation's leaders.

Accelerating Innovation

1. Select major societal challenges and leverage teams across sectors to achieve clearly defined innovation outcomes.
2. Build communities of commercialization and entrepreneurism.
3. Facilitate greater sharing of IP.
4. Create innovation-friendly policy environment.
5. Bridge gaps in the innovation-to-market pipeline.

Regulation / Policy

1. Reform ITAR rules.
2. Maintain federal support for basic research.
3. Retain highly-skilled immigrants educated in the United States.
4. Streamline and modernize the patent process.
5. Remove conflicts in regulations impacting research enterprise (IRS, ITAR, NSF, etc.).
6. Update and enhance the R&D tax credit.

Talent

1. Identify best community college practices and create model curriculums.
2. Expand training in the use of modeling and simulation.
3. Incentivise coop and internship programs for mature workers.
4. Create partnerships between stakeholders to establish these programs.

Innovation Outreach

1. Develop messaging and reach out to target federal and state officials.
2. Create science and technology advisory boards for long-term policymaker education.
3. Promote programs that inspire students to pursue STEM and entrepreneurship.
4. Leverage advisory boards to speak with targeted media.

High Performance Computing

1. Expand business access to HPC.
2. Collaborate and compete globally to have best-of-breed capabilities.
3. Train more computer scientists.
4. Build exoscale machine (1000x faster) by end of decade.

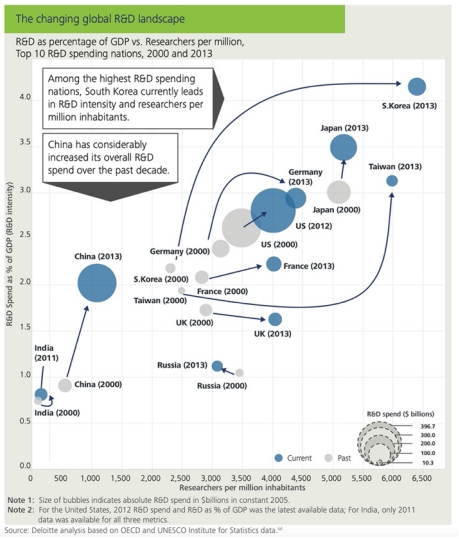
TLSI Working Groups

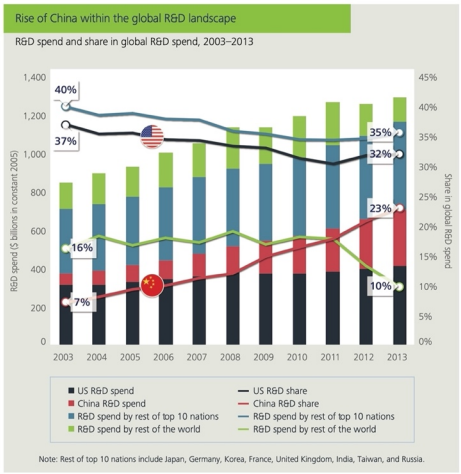
TLSI, 2015-2024

Technology Landscape:

In the past decade, the technology landscape has shifted radically along numerous dimensions, change is accelerating to unprecedented speed, and the United States faces its strongest challenger ever in the technology arena.

The TLSI documented this shift early on, with a significant 2015 study in conjunction with Deloitte – the Advanced Technologies Initiative – to provide important insights on U.S. and global innovation trends, and to highlight the challenges faced by U.S. innovation stakeholders in maintaining or improving their tech-based innovation competitiveness. For the first time, the TLSI uncovered how other nations beyond the United States and the EU – namely, China – were dramatically transforming their innovation investments and national growth strategies. The research and survey work also marked a dramatic change over a very short period of time – the TLSI leaders' perception that the EU would be the most innovation-competitive rival flipped – with China now at the top of the list; and with data for the first time demonstrating China's ambitions.



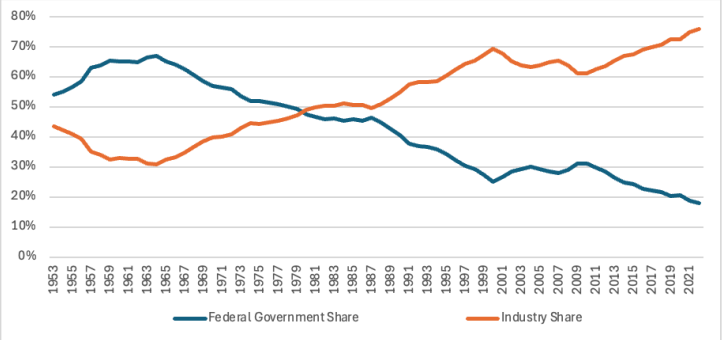


The effort reflects how the country's top tech and innovation leaders were themselves chartering unknown territory brought about by a major technological discontinuity, creating great uncertainty about the future with implications we are struggling to understand. These disruptive changes have brought about a powerful duality—the promise of heretofore unimaginable opportunity, but they also have shaken and threatened the world order.

Ensuring U.S. leadership in critical technologies has risen to the top of the Nation's economic, national security, and geopolitical agenda. These revolutionary technologies include advanced digital and telecommunications technologies, biotechnology, the ever-mounting data tsunami, hypersonics, autonomous systems, quantum, and the apex technology of artificial intelligence. These technologies

are reshaping and driving the global economy, military capabilities, and the global competitive battleground. They are also the platforms from which the industries of the future are now arising.

The private sector's dominant share of U.S. R&D investment continues to widen. In 2009, when TLSI launched, the private sector accounted for 61.2 percent of U.S. R&D investment and the Federal government's share was 31.2 percent. By 2022, the private sector's share had grown to 76 percent, and the Federal share had dropped to 18 percent. The National Science Foundation estimates 2022 total U.S. investment in R&D at $886 billion of which the private sector accounts for $673 billion, and the Federal government for $160 billion. Businesses now play a significant role in U.S. basic research, funding 37 percent ($48 billion) and performing 36 percent ($46 billion) of it, while universities perform 45 percent ($58 billion) and the Federal government funds 40 percent ($51 billion).



The National Science Foundation's mission was expanded. The CHIPS and Science Act established a new NSF Directorate on Technology, Innovation, and Partnerships. In this historic expansion of its mission, NSF is charged with driving technology development, innovation, and growth of regional innovation ecosystems.

A new age of commercial space opened. Moving at a blistering pace, SpaceX is disrupting a market dominated by government for a half century—disrupting satellite launch, space exploration, and the industry's ecosystem. It launched its Falcon 9 rocket 98 times in 2023. In the fourth quarter of 2023 alone, SpaceX lifted 420 tons into space, nearly ten times more than second-place China's 45 tons. SpaceX is aiming for 150 launches in 2024.[2] With its heavy lift rocket in test flight, SpaceX aims to send 100-ton payloads to the moon and Mars at a cost of $10 million a trip.[3]

China has risen as the most formidable strategic competitor the United States has ever faced. China seeks to supplant the United States as the world's economic, technological, military, and geopolitical leader. It has put technology and innovation at the center of its economic, military, and geo strategies. Chinese President Xi said, "Scientific and technological innovation has become the main battlefield of the international strategic game..."[4]

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[2] Space X lifted more than 842,000 pounds into space in 27 launches, compared to China's second place at 90,000 in 15 launches; SpaceX Could Finally Face Competition. It May be too Late, Washington Post, April 15, 2024

[3] What is SpaceX's Starship? It's Really a Mars Shi. New York Times, March 14, 2024.

[4] May 28, 2021, speech by Chinese President Xi Jinping at a meeting of the members of the Chinese Academy of Sciences and the Chinese Academy of Engineering, and the national congress of China Association for Science and Technology.

In 2009, China invested $183 billion in R&D. By 2021, its investment had increased to $620 billion (constant dollars)—a nearly 240 percent increase.[5] It is using every tool in its arsenal to build a science and technology capability rivaling those of the United States—pursing aggressive plans for every strategic critical technology, backed by hundreds of billions of dollars in investment. This includes a multi-pronged strategy to acquire technologies from other countries—especially the United States. It is taking aim at seabed mining, a critical resource for rare metals crucial for producing electronics, clean energy products, and microchips, and setting up institutes on deep sea research, and dozens of colleges on marine sciences, while President Xi has directed that China "master key technologies for entering the deep sea."[6]

China is spreading its wings across the globe, aiming to shape large swaths of the global economic and trading system, and write the rules of the 21st century economy in its own state-directed model. It is using its growing role in multilateral institutions—such as the UN's scientific agencies, WIPO, and international standards setting bodies—to help achieve its geopolitical goals. It seeks to bring other nations into its sphere and global networks through efforts such as Belt and Road Initiative, Digital Silk Road, and Maritime Silk Road.

China seeks to become a world S&T superpower and to use this technological superiority for economic, political, and military gain. Beijing is implementing a whole-of-government effort to boost indigenous innovation and promote self-reliance, and is prioritizing advanced power and energy, AI, biotechnology, quantum information science, and semiconductors. Beijing is trying to fast-track its S&T development through investments, intellectual property acquisition and theft, cyber operations, talent recruitment, scientific and academic collaboration, and illicit procurements.
Annual Threat Assessment of the
U.S. Intelligence Community
Office of the Director of National Intelligence
February 2024

The PRC is the only competitor with both the intent to reshape the international order and, increasingly, the economic, diplomatic, military, and technological power to do it. Beijing has ambitions to create an enhanced sphere of influence in the Indo-Pacific and to become the world's leading power. It is using its technological capacity and increasing influence over international institutions to create more permissive conditions for its own authoritarian model, and to mold global technology use and norms to privilege its interests and values.
National Security Strategy
The White House, October 2022

Members of Congress and the FBI raised alarms about U.S. research collaborations with China and China's expanding footprint on American university campuses. While the scientific community generally views the free and open exchange of information as vital to scientific research, China has employed a variety of mechanisms to influence and exploit openness of the U.S. research enterprise. These include foreign talent recruitment programs, forming partnerships with U.S. research universities, setting up research centers in the United States, financing joint research programs, and

[5] OECD Main Science and Technology Indicators
[6] China Set to Dominate the Deep Sea and Its Wealth of Rare Metals, Washington Post, October 19, 2023.

sending students to the United States for science and engineering graduate studies. Instances uncovered include U.S. researchers failing to disclose foreign funding and associations; theft of intellectual property; and violations of the peer review process by sharing confidential grant applications. Congress and the Executive Branch instituted new disclosure requirements on applicants for federal R&D funding, especially regarding foreign support, and specific policies governing Federal employee and grantee participation in foreign talent recruitment programs. Scrutiny on international collaboration has created pressures at universities, and tension in balancing international R&D collaboration, and protecting U.S. technology and U.S. taxpayers' expectations that they will benefit from public R&D investments made at U.S. universities and national laboratories.

The Federal government continues to target research and innovation in critical and emerging technologies and industries of the future. These include: trustworthy artificial intelligence, quantum information science, advanced communications, microelectronics, nanotechnology, high-performance computing, biotechnology and biomanufacturing, robotics, advanced manufacturing, financial technologies, undersea technologies, and space technologies. Research and technology to address the climate crisis is a high priority. And government has increased the focus of research and innovation on addressing social challenges such as health and inequity, and expanding participation in the science, engineering, and innovation enterprise, with an emphasis on emerging research institutions and historically underserved communities.

The global COVID-19 pandemic demonstrated that the United States can innovate and make a wide range of organizational changes much faster than it has in the past.

The lines between commercial technology, and national security and defense technology have all but disappeared. U.S. defense capabilities are being reshaped by dual-use emerging technologies and game-changing technology-enabled concepts such as artificial intelligence, machine learning, autonomy, next-generation communications, spectrum technologies, space, biotech, and digital technologies that weave defense platforms together for different mission applications and changing battlefield conditions. Leadership in many of these dual use technologies is in commercial firms, high-tech start-ups, universities, and national laboratories. The Department of Defense and defense primes must reach into innovating commercial firms, small businesses, and start-ups to bring advanced technologies to military systems. But the commercial sector is moving so fast, and the investments are so big, the defense industry cannot keep up.

While amazing technology is being developed across the whole U.S. ecosystem, it can take years for it to have its intended impact for national security. Recently, the U.S. Government Accountability Office found that the Department of Defense continues to struggle with delivering innovative technologies quickly. Recent reforms were intended to lead to faster results, but slow, linear development approaches persist. GAO found that leading commercial companies deliver complex, innovative products with speed through iterative cycles of design, development, and production. But the average major defense acquisition program (MDAP) yet to deliver initial capability plans to take over 10 years to do so. Cycle time is increasing. GAO found that, for MDAPs major that have delivered

capability, the average amount of time it took to do so increased from 8 years to 11 years—an average increase of 3 years from their original planned date.[7]

Rising geopolitical risk has given strong momentum to repatriating the manufacturing of critical technologies back to the United States, particularly microelectronics, and securing supply chains for critical materials and minerals. The CHIPS and Science Act, passed in 2020, appropriated $50 billion for: financial assistance to establish semiconductor fabrication, assembly, testing, advanced packaging, or R&D in the United States; a new National Semiconductor Technology Center; a National Advanced Packaging Program; microelectronics metrology research; and ManufacturingUSA institutes on semiconductor manufacturing. Two-hundred million was provided for workforce education and training, $2 billion for a Department of Defense National Network for Microelectronics Research and Development, and $500 million for international technology and supply chain security and innovation activities.

The "valley of death" became a stubborn bottleneck in U.S. innovation. The "valley of death" is a persistent 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. In the valley of death, 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 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 has made efforts to bridge the valley of death, for example, funding an extension of Phase II Small Business Innovation Research program grants, and providing funding for prototype development and pilot demonstrations.

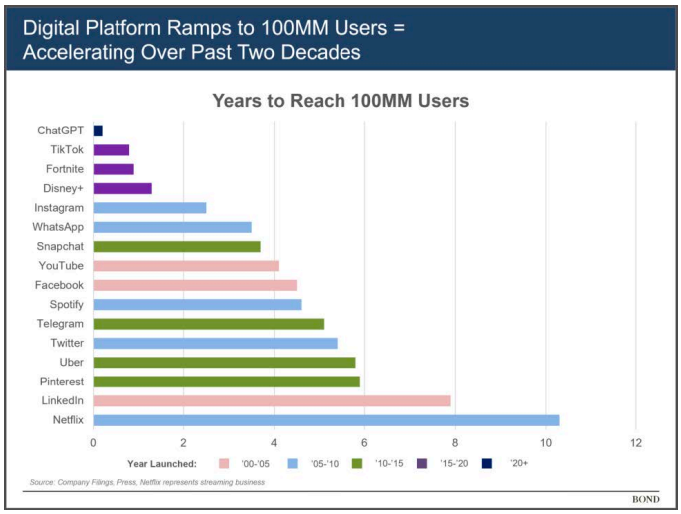
The Federal government has taken a large role in building innovation ecosystems beyond the U.S. coastal superstars.

- In 2023, the Department of Energy awarded $7 billion to launch seven Regional Hydrogen Hubs.
- In 2023, the National Science Foundation selected ten inaugural Regional Innovation Engine hubs—on technologies such as advanced energy, biotech, advanced materials, advanced computing, semiconductors, robotics and advanced manufacturing, and disaster prevention and mitigation. If the engines progress toward their milestones, they could receive $160 million each over ten years.
- In 2023, to fulfill authorities appropriated under the CHIPS and Science Act, the Department of Defense awarded nearly $240 million to eight regional innovation hubs that form its Microelectronics Commons.
- In 2024, the U.S. Department of Commerce awarded $504 million to 12 technology hubs across the United States on technologies ranging from autonomous systems, quantum, and biotech to energy, critical minerals, semiconductor manufacturing, and materials manufacturing.

[7] Weapon Systems Annual Assessment, DOD Is Not Yet Well-Positioned to Field Systems with Speed, Government Accounting Office, June 2024.

Researchers achieved nuclear fusion ignition. After 60 years of work, on December 5, 2022, researchers at Lawrence Livermore National Laboratory's National Ignition Facility for the first time anywhere by any approach achieved a fusion experiment that produced more fusion energy than the laser energy required to trigger the reaction—a huge advancement for the field, repeated in four subsequent experiments. Nuclear fusion has the potential to deliver an inexhaustible supply of cheap clean energy. The United States has 25 companies working on different concepts, and most of the investment. In 2023, the Department of Energy awarded $43 million to eight of these companies to fund R&D and deliver within 18 months an early fusion pilot plant design.[8] The White House and many commercial companies are targeting the early 2030s for putting fusion energy on the grid, and a few start-ups have even more aggressive timelines.

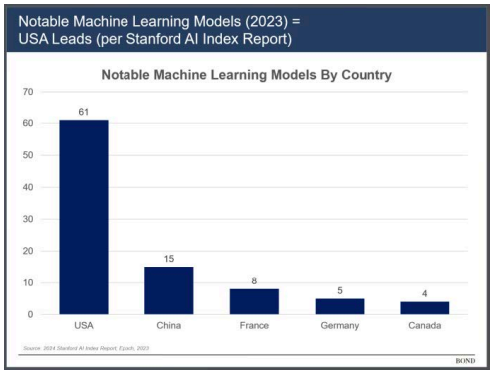
The Age of AI suddenly arrived. In 2023, a generative AI model—ChatGPT—was released to the public, reaching 1 million users in 5 days, and 100 million users in two months.[9] According to BOND's June 2024 report, this was the fastest user ramp ever for a standalone product; and generating the fastest software ramp ever (OpenAI hit a $2 billion revenue run rate in the first full year post-launch of ChatGPT).



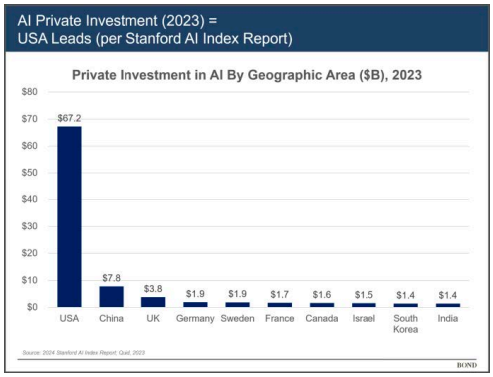
The advance of AI will drive the biggest and fastest technology disruptions in history. Businesses, researchers, educators, government officials, and others are beginning to experience disruption as AI begins to transform the relationships between human and machines, shatter the time and cost calculus for a widening array of human endeavors, rewrite the process of scientific discovery, and drastically alter military capabilities and the very character of war. It could drive a collapse in some product life cycles, supercharge the forces of creative-destruction, and propel a leap in productivity. In a recent study, top economists estimated that we could see a near doubling of output after 20 years from an AI-enabled productivity growth rate 44 percent higher than the baseline projections of the U.S. Congressional Budget Office.[10]

[8] Preconceptual design addresses the same issues as a conceptual design but at lower levels of fidelity and with greater uncertainties.
[9] ChatGPT Sets Record for Fastest-Growing User-base—analyst note, Reuters, February 2, 2023.
[10] Machines of the Mind, The Case for a n AI-powered Productivity Boom, Martin Neal Baily, Erik Brynjolfsson, and Anton Korinek, Brookings, May 10, 2023.

The United States is positioned as the global AI leader. In 2023, U.S. companies released 61 notable machine learning models, compared to 15 for China, 8 for France, 5 for Germany, 4 for Canada, and no country comes close to the $67 billion U.S. investment in AI in 2023, and spending is only increasing. The next highest was China, with $7.7 billion.[11]



The world's largest companies by market cap—Microsoft, Apple, Nvidia, Alphabet, and Amazon—are all competing fiercely for leadership in AI. And we are seeing some of the biggest injections of capital into a specific technology in the history of Silicon Valley. In the first quarter of 2024 alone, Microsoft spent $14 billion, Google spent $12 billion, and Meta spent more than $6 billion. They all increased their spending projections for the year ahead.[12] These three companies, along with Apple, are the top R&D spenders in the world.



The AI boom is rapidly increasing demand for compute power, placing pressure on American data centers and the supply of electricity that powers them. The IEA reported that data centers' total electricity consumption could double to more than 1,000 terawatt-hours by 2026.[13] That's roughly equivalent to the electricity consumption of Japan. IEA forecasts that electricity consumption from data centers in the EU in 2026 will be 30 percent higher than 2023 levels. By 2033, power demand from Europe's data centers could be equivalent to the total power consumption of Portugal, Greece, and the Netherlands.[14] Ireland's AI-related consumption could reach 32 percent of the country's total electricity demand in 2026.[15] In the United States, a new study reports that data centers could consume up to nine percent of electricity generation by 2030, more than double the consumption today.[16]

[11] AI Index: State of AI in 13 Charts, Stanford University Institute for Human-Centered Artificial Intelligence, April 15, 2024.
[12] Alphabet, Microsoft Earnings Show Heft AI Bets are Driving Growth, Reuters, April 26, 2024; Big Tech Keeps Spending Billions on AI. There's No End in Sight, Washington Post, April 25, 2024.
[13] Electricity 2024, Analysis and Forecast to 2026, International Energy Agency, January 2024.
[14] Powering Up Europe: AI Data Centers and Electrification to Drive +c.40%-50% Growth in Electricity Consumption, Goldman Sachs, April 29, 2024.
[15] Electricity 2024, Analysis and Forecast to 2026, International Energy Agency, January 2024.
[16] Press Release, EPRI Study: Data Centers Could Consume up to 9% of U.S. Electricity Generation by 2030, Electric Power Research Institute, May 28, 2024.

The EU developed the first-ever legal framework on AI, focused largely on risks in specific uses of AI. To date, the Federal government has yet to develop an AI regulation, but a Presidential Executive Order is focused on advancing trustworthy AI technology that protects people's rights and safety, and harnesses it to accelerate the Nation's progress. Federal agencies are to prioritize fundamental and translational AI research to make AI trustworthy, equitable, robust, safe, secure, and both rights- and privacy-preserving.

New initiatives extend U.S. global statecraft to critical technologies. Rules for the 21st century technology-driven global economy, technology standards, and regulations on powerful emerging technologies are being set in international institutions, with competing visions and values on what these models should be. The United States is deploying a new technology statecraft and working with allies and like-minded nations to ensure these new rules of the road adhere to free market principles and democratic values.

For example, the U.S. Department of State established a Special Envoy for Critical and Emerging Technology to cooperate with allies and partners on critical and emerging technologies; lead planning for international technology diplomacy to support national security priorities; and coordinate policy around new global technology developments including in AI, quantum, and biotechnology. The U.S.-EU Trade and Technology Council, formed in 2022, is focused on transatlantic cooperate on development and deployment of new technologies such as AI, 6G, quantum, and biotech based on shared democratic values, including encouraging compatible standards and regulations. Pillar II of AUKUS—a trilateral security partnership for the Indo-Pacific Region between Australia, the United Kingdom, and the United States—aims to improve joint capabilities and interoperability in cyber, AI, quantum, and undersea capabilities. Recently launched, NATO's Defense Innovation Accelerator for the North Atlantic is supported by joint funds to support competitively awarded grants and accelerators to develop technologies that, if successful, can move to the warfighter, NATO nations, or industrial base.

The TLSI Call to Action
– In Detail –

Over the past year and building on the work and findings of the past 15 years, the TLSI convened three Dialogues under the leadership of its co-chairs Dr. Patricia Falcone, Deputy Director, Science and Technology at Lawrence Livermore National Laboratory; Dr. Sally Morton, Executive Vice President, ASU Knowledge Enterprise, Arizona State University; and Dr. Steve Walker, Vice President and Chief Technology Officer, Lockheed Martin. Participating CTOs and technology experts from technology-intensive industry sectors, universities, national laboratories, and the Federal government considered the unprecedented speed and scale of today's technological change and the effects on the U.S. innovation system.

- On June 29, 2023, the Council convened its Summer and 27th TLSI Dialogue, hosted by Lockheed Martin at its Advanced Technology Center in Palo Alto, California. Participants explored the forces, challenges, and opportunities reshaping the U.S. defense industrial base, and ways to develop an adaptive and agile industrial base to meet U.S. economic and national security needs.

- On September 21, 2023, the Council convened its Fall and 28th TLSI Dialogue, hosted by the U.S. Department of Energy's Lawrence Livermore National Laboratory in Livermore, California. Discussions were centered around three key themes: changing the culture of research and innovation ecosystems, enhancing the innovation workforce in critical technologies and industries, and building innovation ecosystems through national domestic strategies.

- On February 26, 2024, the Council convened its Winter and 29th TLSI Dialogue, hosted by Arizona State University. Discussions were centered around developing recommendations and a Call to Action for the next Administration and our Nation's leaders.

This Call to Act reflects their findings and recommendations on what the United States must do to ensure its continued national and economic security, geopolitical leadership, and future prosperity for its people in a world in which technology has taken center stage in each of these domains and transformational change is accelerating. It proposes a framework to guide collaboration among government, industry, universities, and U.S. allies to advance and ensure mutual security interests.

A Strategy for Boosting U.S. Leadership in Developing and Deploying Disruptive Technologies with Speed and at Scale for Economic Growth, National Security, and Geo-Leadership …

U.S. leaders must put forth a new narrative on the primacy of technology in the national interest.

- U.S. leaders should advocate a new technology-centric national narrative. America's innovation enterprise has long driven global innovation, conquered the frontiers of emerging technology, made the breakthroughs, and propelled U.S. leadership in high-tech markets. This has been a tremendous source of American global power.

  But we have entered a new age defined and world order being reshaped by rapid technological advancement. Amid multiple technology revolutions and their convergence, the United States is being challenged across the technology landscape like never before. Geostrategic competitors seek to unseat us and undermine the current world order with overmatch in the key technologies of the future, eroding our economic competitiveness, military superiority, and geopolitical leadership. More than anything else, winning the competitive challenge for the future, defending the current world order, and our global leadership rest with the strength of our ability to innovate with speed and at scale.

Across the U.S. R&D enterprise, emphasize the importance of use-inspired research to meet economic and national security needs.

- Recognize that the prevalent siloed model of techno-industrial policy—where universities are viewed as fundamental research drivers, the commercial sector operates in markets, and the government is confined to its missions—may need to change with the emergence of dual-use technologies and a broader view of technology and innovation in the national interest.

The United States should expand investment, encourage multidisciplinary research collaboration, and foster the development of innovation ecosystems in areas of technology convergence.

- The convergence of artificial intelligence with other enabling technologies—such as biotechnology, advanced manufacturing, autonomous systems, and advanced computing—holds significant potential for opening a new age of discovery and innovation frontiers, new models of production, a flow of new products, personalized medicine, and novel solutions to global problems, creating significant economic benefits, strengthening national security, and driving productivity gains.

Ramp-up engagement, develop new pathways and interfaces, and reduce the transfer time gap to move new technology faster from developers in universities and national laboratories to users across industry—to match or drive the pace of change, quickly seize emerging technology and market opportunities, scale innovations faster than our competitors, and deploy solutions to global grand problems more quickly:

- Marquee Federal research sponsors should place greater emphasis on working with industry, technology translation, and commercialization as a priority for gaining R&D awards and other support.

- The Federal government—in partnership with industry, the research community, and groups focused on advancing societal progress—should identify the highest pressing economic, national security, societal, sustainability, and government mission problems or needs. The Federal government and other institutional leaders should act as catalysts to mobilize a community of people to solve a problem or need, and align R&D and program investment. As part of the process, identify the potential for a robust market for the private sector.

- Expand cooperative extension for research and technology translation across other industry sectors and user communities. Extension services would connect university faculty to local businesses, community organizations, interest groups, and citizens, disseminating new knowledge and technology, and providing practical education to targeted audiences. Research faculty would engage with businesses and the community of potential users to better understand their needs, including current and future research priorities. Community organizations, industry partners, and local government agencies can identify where infrastructure investments as well as education and skill building efforts are needed. These extension centers can be used for both commercial and non-commercial translation, for example, in building climate resilience and greater sustainability.

- Devote a small percentage of funds in each Federal research grant to technology transfer activities and/or operations for education, outreach, and patenting.

Elevate the imperative of U.S. leadership in standards given the duality of advanced and emerging technologies in economic and national security, recognizing that friendly and hostile competitors use standards setting to gain commercial dominance for their technology champions, get their domestic technology specifications into global standards, use them as non tariff barriers to market entry, and protect their existing or nascent industries.

- Forge a new compact for a pro-active standards-setting process that reinforces the primacy of private sector leadership, and strengthens U.S. engagement and elevates U.S. firms' seat at the table in global standards-setting bodies.

With the lines between commercial technology and defense technology all but disappearing, and the intertwining of economic and national security, elevate the focus on research security and the need for stronger research security plans. Many institutions, particularly small institutions are struggling with research security issues and new rules requiring institutions that receive more than $50 million in Federal R&D funding to develop a research security plan.

Commented [CM1]: Need a recommendation on universities developing research security plans.

- NEED RECOMMENDATION

- Develop clearer rules and guidelines for partnerships, especially around intellectual property and data management.

- Offer training in research security to small businesses and start-ups engaging with the Department of Defense, and among researchers and students at universities.

- Launch an education campaign directed at small businesses, start-ups, university researchers, and students to raise awareness of threats to intellectual property. Train student researchers on private sector requirements for managing and protecting intellectual property and data. This is especially critical in university-industry partnerships, and where students do internships or co-ops with industry.

Expand investment and activities focused on rapid scaling of critical technologies. Focus on propelling technology, and clearing pathways and barriers to moving it quickly into deployment and scaling. This will require engagement with players and institutions beyond the research and technology community.

- Use pilots and demonstrations to move technologies more quickly toward deployment at scale. University and national laboratory researchers, industry, and other non-governmental partners should engage at the beginning of Federally-funded pilots and demonstrations. Early engagement will help researchers better understand industry requirements for commercialization and manufacturing, identify potential applications and industry uses early, provide mechanisms for cost-sharing the de-risking of precompetitive technologies, while industry partners can plan for commercialization and deployment.

- In pre-competitive consortia focused on critical technologies, engage downstream players that will ultimately be needed for commercialization and deployment at scale. For example, a pre-competitive consortium on autonomous vehicles could have auto manufacturers, vehicle safety and regulatory experts, legal and insurance companies, etc., in addition to researchers and technology developers.

- The Federal government should consider assessing potential regulatory impacts at the conclusion of key research and technology development projects—whether there is a need or not for regulatory action, or if existing regulations need to be updated or changed. Establish a corps of Tech Reg Sherpas to help small companies with innovative technologies navigate the regulatory system.

Build and bolster innovation capacity and capability across the Nation by fostering and expanding placed-based and place-making innovation beyond the high-tech superstars on the U.S. coasts.

- State and local governments should increase resourcing of state and regional innovation efforts such as investing in public university research, R&D infrastructure, and programs aimed at translation, deployment, and commercialization. Communities should foster the physical co-

location of innovation assets, for example, by building innovation districts. Regions should consider cost-sharing investments to establish large-scale or expensive infrastructure shared by universities and their industry partners. Where assets can be accessed through the Internet or other remote technologies, research institutions across the region, country, or even among U.S. allies should form collaborations and partnerships to co-fund and operate them, and provide access regardless of location.

- To build support for expanding state and local investment in research and placed-based innovation, universities and state and local political leaders should offer compelling narratives about the importance of R&D and its commercialization to the state, local and regional economy, industrial base, jobs, and national security, helping constituents understand the value proposition for their tax-funded investments.

- Develop models to coordinate where appropriate the efforts of the major innovation hubs supported by Federal investments, to better leverage them for both economic and national security, and develop clear pathways to transition their innovations into production. This includes leveraging the 37 hubs and regional innovation engines in which the Federal government is committed to investing as much as $9 billion.

- Ensure skills scale in tandem with scaling of new technologies. Across the Nation, reestablish skilled trade, vocational, and technical education programs and programming for the modern technology era. This includes high school work release and internship programs that allow students to take required high school courses, technical courses, and work at local businesses. These programs should focus on emerging technologies, production processes, and industries such as 3D printing, autonomous vehicles, and working with hydrogen. These could begin through partnerships with local technical schools in the regions where federally-supported technology, energy, and manufacturing hubs are located.

Reimagine the industrial base developing dual use technologies and serving national security. In addition to – perhaps rather than – the Department of Defense and defense primes, technology leadership is now in commercial companies and universities; they need to be brought more fully into the national security technology ecosystem. Defense systems integrators could serve as a "bridge" between commercial innovation and defense application., working with leading edge commercial firms to integrate and deliver their advanced technologies to the Department of Defense. In addition, the Department has established dozens of organizations, programs, and other initiatives to foster partnerships with commercial companies. However, this has created "silos of opportunity" that are difficult for commercial companies, especially small commercial companies, to navigate. Many small businesses remained challenged in maturing their innovations and transitioning them to national security uses.

- The Department of Defense should catalyze a new technology and innovation ecosystem to meet national security needs by opening competition to more players, and integrating and leveraging the different capabilities and skill sets of commercial firms, defense primes, universities, and the venture capital community.

- The Department of Defense should optimize its own R&D enterprise to leverage this new DIB and what it has to offer. This means reforming the DOD lab enterprise and the many new agencies and organizations stood up to engage a broader section of the private sector. The Department of Defense should rationalize, streamline, and adequately fund its organizations and programs that serve as gateways to the defense market for commercial firms of all sizes. USD(R&E) should take the lead here and optimize the labs and this new outreach for success.

- National laboratories should serve as conveners for pre-competitive consortia and research initiatives, bringing together industry, defense, commercial sectors, and universities for collaborative research.

- The Department of Defense should consider procurement requirements that stress the importance of a defense contractor's partnership with a commercial entity. Public-private and private-private partnerships should be encouraged through solicitations asking these partnerships be developed to solve DOD challenges.
- A new DIB could leverage the existing workforce and manufacturing capabilities within the traditional DIB. This will ensure a smooth transition and minimize disruption during the modernization process. Joint manufacturing efforts between commercial and defense companies could also be pursued.

- The Federal government must make bigger bets and assume greater risk to drive innovation more quickly. IThese should be national initiatives that encourage the entire R&D ecosystem be brought to bear to solve national problems.
- For small businesses performing Department of Defense-funded research and technology development, the Department should articulate clear pathways and provide support in advancing their innovations to TRL-5 and above and help transition them to a national security application, a systems integrator, a defense service, or program of record.

- Establish secure facilities for interactions between universities, companies, and the Department of Defense. Perceived as neutral grounds, universities could be a place to establish secure facilities for multiple users. Larger firms could help small businesses and start-ups fund secure facilities.

Engage U.S. allies to expedite the research, development, and scaling of technologies critical for economic security and joint security.

- Identify specific technology and scientific areas in which collaboration would benefit the United States and its allies, where allies have leading edge specializations, and where allies need to build capacity as targets for collaboration.