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Key Points

- **Rapid globalization of science and technology (S&T) capacity presents a serious and long-term risk to the military and economic security of the United States.**
- **To maintain U.S. preeminence, our domestic science and technology enterprise requires a new paradigm to make it more agile, synchronized, and globally engaged.**
- **U.S. technological competitiveness depends not only on research but also on legal, economic, regulatory, ethical, moral, and social frameworks, and therefore requires the vision and cooperation of our political, corporate, and civil society leadership.**
- **Re-organizing our domestic S&T enterprise will be a complex task, but recommendations presented in this paper could be first steps on the path to maintaining our future technological security.**

Technology and National Security: The United States at a Critical Crossroads

by James Kadtke and John Wharton

American leadership in science, technology, and innovation (ST&I) has been the foundation of U.S. national security for decades. Advanced technology, along with America's ability to operationalize it into transformational capabilities, has long given us a military advantage. This advantage has provided superiority on the battlefield and for our broader national security apparatus. Today, however, our technological superiority is increasingly being challenged by near-peer and asymmetric competitors. Globalization of science and technology, emerging and unpredictable threats (both manmade and natural), conventional and emerging weapons of mass destruction, and an inversion of technology flow from the private to public sectors all present challenges to our national security.

To meet these challenges, the United States must develop a clear, synchronized, and actionable national strategy that drives advances in science, technology, and innovation in all domains (land, sea, air, space, cyber) to assure our economic and national security. While maintaining military technology overmatch remains a key national security objective, promoting technology development by the private sector at home and around the world and then harnessing that development in ingenious ways will be increasingly important for economic prosperity as well as for national security. The recently released National Security Strategy of the United States also points to research, technology, invention, and innovation as key elements of our national power.[1] The Trump administration has a historic opportunity now to re-invent the U.S. Government's relationship with the private sector and the international community to retain our country's technological dominance throughout the 21st century.

Our national security ST&I enterprise must be able to meet rapidly evolving threats, establish and maintain strategic partnerships, employ swiftly changing technologies, cope with diminishing resources, and benefit from accelerating globalization. The U.S. national security ST&I enterprise derives its strength from Federal agencies in collaboration with academia, industry, and global partners. If we are to continue to maintain technological preeminence and ensure our national security, we must evolve and adapt to meet these emerging threats and challenges. The United States must think strategically, and in fact *geostrategically*,[2] to manage and enhance its national ST&I resources.

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America is at a critical crossroads. New generations of advanced technologies are on the verge of dramatically changing global society.[3] Many other nations are now investing heavily in research and commercialization capabilities to create or exploit these new advances. At the same time, the United States has often been de-investing in many technology areas over the last decade or more and is on a path to losing its global competitive advantage. This will have dire consequences for the future of our economy, military, and society at large. However, with a firm recommitment to enhanced and strategic investments in science (research), technology (commercialization), and innovation (cultural change), the United States can retain international leadership for decades to come.

The Global Technology Revolution

For decades, advanced ST&I activities were mostly conducted by a handful of wealthy nations. Today, however, there is a radical change happening in *how* and *where* science and technology development are being conducted. The commercialization and globalization of the internet, which has led to tremendous innovation in social interaction and commerce over the last two decades,[4] is also now creating a *global scientific enterprise*. Scientists the world over can easily collaborate and share data and analytic tools. Technology communities from different disciplines are cross-fertilizing to create new disciplines (for example, nano-robotics). Multinational research companies move ideas, people, and resources across national boundaries with ease to maximize efficiency. A growing community of "do-it-yourself" scientists who can conduct fundamental research in their own homes are appearing worldwide. And most importantly, a growing number of countries are investing heavily in science, technology, and commercialization activities as a path to high-value economic growth and increased military capabilities.

The result of these trends is that the rate of innovation today in science, technology, and high-tech product development is unprecedented in history and continues to accelerate.[5] New generations of highly advanced technologies are already being deployed throughout global society and they will dramatically alter our way of life, as well as our economic systems and military capabilities. Nations, corporations, universities, and tech-based consortia are pushing hard to develop and deploy these advanced technologies since the financial and economic returns are potentially enormous. Some of the revolutionary technologies that will appear within the next decade include:

- A continued buildout of information and communication technology infrastructure (WiFi, satellites, mobile devices) will provide cheap or free internet access to virtually everyone around the globe. A June 2017 report by the U.S. Army War College has warned of the "coming age of unbridled hyper-connectivity."[6]

◆ Human–machine interfaces where mobile devices will be replaced first by wearables, then embeddables, and eventually devices directly interfaced to the brain, raising serious new privacy and security issues.[7]

◆ Using synthetic biology and gene editing, scientists will be able to create entirely new life forms that can perform a variety of radically novel tasks but at the same time, pose unknown risks.[8]

◆ Artificial intelligence and advanced robotic devices will become highly functional and cheap, and personal robots and autonomous infrastructure (such as driverless cars) will be common but may create dangerous new cybersecurity vulnerabilities.[9]

◆ Production and distribution facilities will become largely autonomous and seamlessly interfaced globally (that is, the Industrial Internet of Things), creating a mega-infrastructure for industry potentially not controlled by any one nation, which could displace millions of workers worldwide.[10]

◆ Commercial nanotechnology companies will create completely new kinds of materials and products that will make obsolete many existing product lines, for example, smart materials that automatically heat, cool, change optical properties, or never wear out, as well as nano-machines. These creations, however, may raise serious environmental and military risks.[11]

◆ Facilitated by nanotechnology and synthetic biology, new generations of renewable energy technologies will be deployed, for example, highly efficient solar cells or energy harvesting technologies, which may disrupt the current global economics of energy.

◆ Enabled by cheap launch capabilities (for example, by SpaceX), commercial space companies may by 2020 begin mining asteroids and the moon and fabricating products in space, but widely available space access may also facilitate wholly new mechanisms for malicious actions by rogue states or terrorists.[12]

Many, if not most, of these disruptive technologies are the direct result of decades of research investment by the U.S. Government and private sector. However, because of a variety of factors, the next generation of new technologies may likely be commercialized and produced outside of the United States, which will create a strategic and long-term threat to our nation's well-being.

America's Strategic Technology Challenges

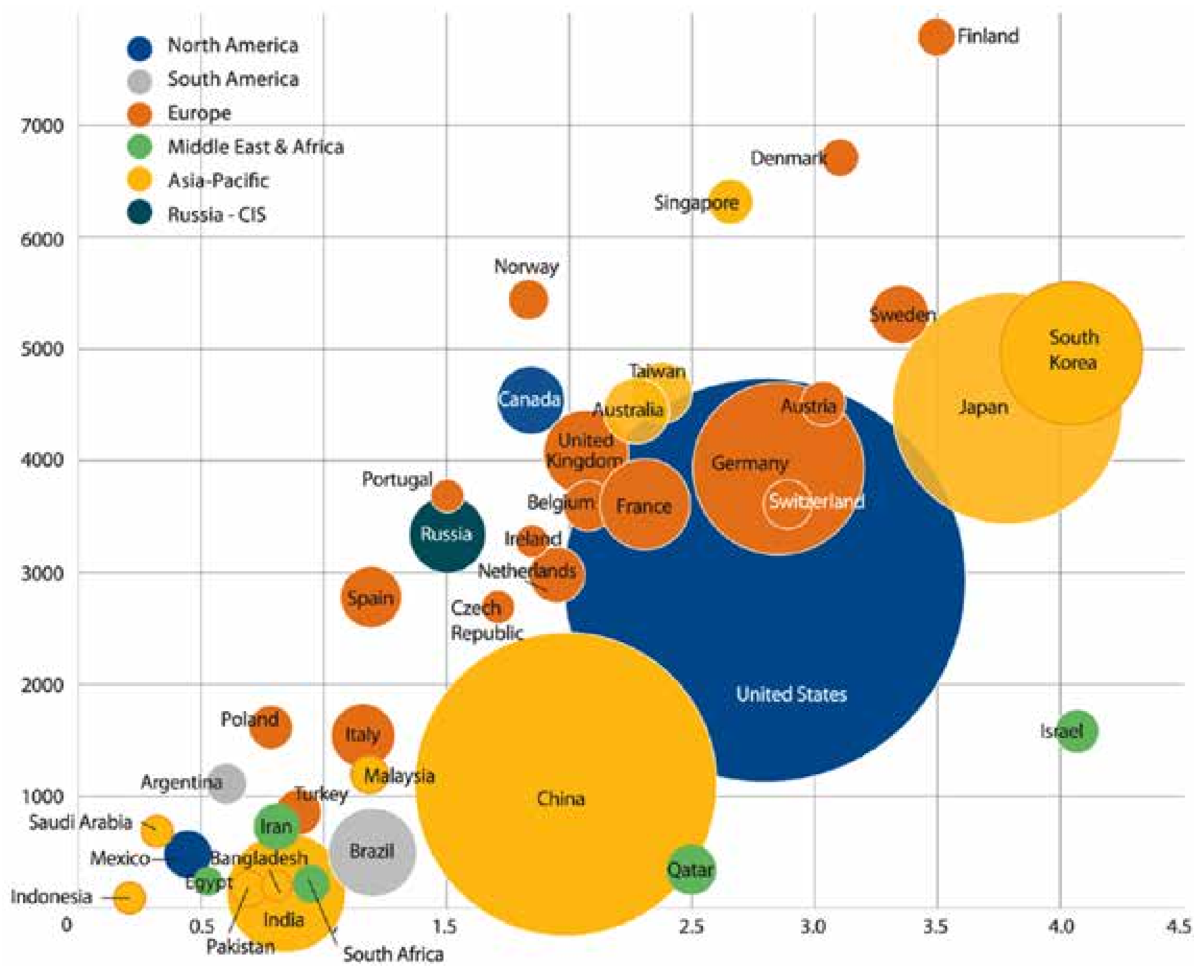
The United States has become a great power in part because it has historically fostered creativity, entrepreneurship, and innovation. After World War II, because of the vision of President Roosevelt's science advisor Vannevar Bush, the United States created the first S&T enterprise, a formal collaboration between the Federal Government, corporations, and academia. Funding investments in this enterprise are widely credited with creating over half our growth in GDP since World War II and have enabled one of the most powerful militaries in the world. Yet today, the dominance of our S&T enterprise is on the verge of being overshadowed by international competition. This is due to multiple factors both domestic and foreign.

Many countries are now dramatically increasing their investments in science, technology, and commercialization, particularly in Asia, and including many nontraditional players such as Vietnam and Singapore. A May 2016 report by the National Science and Technology Council pointed out the "dramatically increased capacity for science and technology around the world."[13] At the same time, U.S. government funding (in constant dollars) has remained roughly flat over the last couple of decades and has even gone down since 2013. Moreover, the fraction of U.S. investments in the global S&T enterprise has dropped from about 39 percent in the late 1990s to about 31 percent by 2015.[14] The trend therefore is that the U.S. S&T enterprise will be a progressively smaller part of the global S&T enterprise, and the United States will produce a progressively smaller fraction of scientific breakthroughs and high-tech products in the future. This portends a future in which the United States will be driven into economic decline, and our military strength will be compromised because we no longer have the technology dominance we have depended on since the 1940s (see figure).

In addition to funding, many common practices by foreign powers are undercutting the U.S. technology base. This includes strategic and coordinated cyber-theft of intellectual property, unfair or asymmetric access to technology markets and trade, aggressive foreign acquisition of small U.S. tech companies, poaching of intellectual talent, lax or non-existent foreign environmental and health regulations, and corporate espionage, among others. The U.S. Government has often turned a blind eye to many of these issues over the years, and this has compromised our leadership in several critical technology areas (for example, aerodynamic and hydrodynamic design).[15]

Within the United States, we have been witnessing the slow degradation of the competitiveness of our own domestic S&T enterprise. Decreased or inconsistent funding of S&T programs or target disciplines is a key factor and, more broadly, the lack of clear national strategic technology plans, as well as political support for

Figure.



The size of the circles reflects the relative amount of annual R&D spending by the indicated country. Note the regional grouping of countries by the color of the balls.

research investments and commercialization frameworks. Other factors affecting the health of our national S&T enterprise include burdensome regulation of tech companies, regulatory uncertainty in emerging technology areas, inconsistent research tax incentives, the complex Federal contracting and acquisition process, poor public-private sector cooperation in many areas, and the *technological literacy* of our workforce. All these factors affect or degrade the efficiency and profitability of our S&T enterprise and make us progressively less competitive in the globalizing technology landscape.

From a grand strategic perspective, one might observe that in the decades to come, in a world dominated by pervasive advanced technologies, the countries that are most able to create, acquire, and utilize these disruptive technologies will lead the world. This *technological capacity* will be one of, if not *the*, most important global resources.[16] *Technological capacity will become the new oil.*

Organizing for Future U.S. Technological Leadership

Our future well-being and security as a nation depends on us maintaining technological preeminence throughout the coming decades. Our national political leadership, working in concert with U.S. corporate leaders and academia, have a historic opportunity to change our national trajectory to ensure this future. This will require more than the occasional Federal technology initiative, political photo op, or unfunded mandates that have characterized many U.S. ST&I commitments over the last decade. It will require a re-thinking of the framework for our national ST&I enterprise and developing a new paradigm for public-private coordination with a commitment to shared goals. Fortunately, the issue of maintaining U.S. technological leadership has been increasingly debated in public policy circles, and there is growing political support to act now.[17]

From a grand strategic perspective, a new competitive ST&I paradigm should be based on enhancing the speed and efficacy of our national decision cycles, improving our Whole-of-Government planning and investments, fostering Whole-of-Society partnerships by reducing barriers to public-private cooperation, and creating international strategies to succeed in a multi-actor, hypercompetitive globalized society. In short, the United States can prevail in this future environment by *making better decisions faster* and building an ST&I enterprise that is more *agile, synchronized, and globally engaged*.

Implementing such a national strategic re-organization for ST&I will be a complex task and require time and careful planning. However, many key steps could be taken now to begin this process. Some of these key recommendations are discussed below.

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Strategic Technology Decision Support for Leadership

The President should consider creating, by Executive Order, an overarching National Security Technology Initiative (NSTI), which will define the goals, authorities, and government elements responsible for re-organizing the U.S. ST&I enterprise. To help facilitate the NSTI, he should also convene a public-private National Security Strategic Innovation Council to study, plan for, and help oversee innovative reforms to our ST&I enterprise. It should include senior Federal agency staff, C-level corporate leaders, experts from academia and think tanks, and perhaps a White House lead.[18]

The President should also consider incorporating strategic technology issues into the responsibilities of the National Security Council, either through a dedicated staff member or as part of the Strategic Planning desk. The President should also make full use of the President's Science Advisor and his staff to help fully implement these strategic initiatives and to coordinate across government agencies and with the private sector.

Whole-of-Government Initiatives

Proposed Federal initiatives should require that Science and Technology Strategic Plans be created by each agency—and for the government as a whole—which are timely, realistic, actionable, and regularly updated. Top-level funding should be increased for ST&I programs across the government, and, in particular, focused cross-agency technology initiatives should be created in technology areas that are critical and rapidly evolving (for example, autonomous infrastructure). Recent Government Accountability Office recommendations on managing emerging technologies should be reviewed,[19] and an oversight council should be established to analyze government ST&I spending aimed at reducing stovepiping, duplication of effort, and obsolete programs as well as to re-direct valuable resources to make the ST&I enterprise more efficient. Additionally, mechanisms and incentives should be created to foster and reward innovation by Federal ST&I personnel, speed acquisition actions, and make it easier for private sector individuals to spend time in or collaborate with government offices. Finally, the government should institutionalize the use of foresight and futures-enabled strategic planning across Federal agencies because these capabilities will be increasingly critical in creating informed decisions and plans in a global environment whose transformation will continue to accelerate.[20]

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Whole-of-Society Initiatives

A key goal of these initiatives should be to reduce the complexity of the Federal Government in partnering with the private sector. Government contracting regulations should be streamlined so they are simpler, more flexible, and reduce burdensome regulation of technology businesses and new technology products, especially for small research companies. Another goal should be to expand the use of public-private partnerships (PPPs) among the Federal Government, state and local governments, companies, universities, and nongovernmental organizations, particularly for regional tech-based economic development initiatives and targeted technology areas (for example, autonomous vehicles or commercial space).

Federal programs and PPPs to promote entrepreneurship and startup creation should also be expanded, for example for *Government Strategic Investment initiatives*,[21] or other mechanisms such as those proposed in the *Startup Act* introduced in the U.S. Congress in September of 2017. Another key initiative should be to expand Federal support and partnerships for Science, Technology, Engineering, and Math education, as well as workforce training and lifelong learning—including programs with national security relevance—to enhance the technical literacy of the U.S. workforce.

International Engagement

On the international front, an important action would be to enhance and integrate various government functions for *technological intelligence*, foster the field of *geo-innovation*,[22] and provide accurate and comprehensive analysis of global technology developments for national leadership. The Federal Government should also help to aggressively engage with International Technology Standards Organizations to help influence emerging technology markets and improve U.S. long-term competitiveness. *Science diplomacy* should be enhanced as a tool for U.S. soft power and international security cooperation and to address unfair trade and asymmetric market access for U.S. technology products.[23] Finally, better frameworks and programs should be developed for the U.S. Government and companies to help harvest intellectual property, resources, and talent from the global S&T enterprise, including sensitive technologies, and to incentivize U.S. ST&I resources to remain in the United States.

Conclusions

The science and technology enterprise of the United States is still the best and most productive in the world. It also has the greatest capacity to create rapid economic growth and unparalleled military capability. Yet its global competitiveness is increasingly hampered by inefficiencies, vulnerabilities, and the lack of a clear, synchronized, and actionable national strategy that leads in all domains to assure our economic, homeland, and national security. Our competitive advantage may therefore rapidly evaporate in the face of burgeoning international competition. Our once near-unilateral dominance in ST&I may soon be replaced by an era of *contested equality*.[24]

What is often not appreciated outside of the ST&I community is that development and commercialization of advanced technologies involves far more than funding. A vigorous ST&I enterprise involves a complex ecology of factors including legal, economic, regulatory, ethical, moral, and social frameworks. The legacy U.S. ST&I enterprise, combined with a burdensome Federal acquisition process, has increasingly evolved gaps, redundancies, inefficiencies, and many "valleys of death," which make it less efficient than many countries and nonstate actors with newer, smaller, or more monolithic ST&I systems. In this regard, we will need the vision and cooperation of our political, corporate, and civil society leadership to create new organizational models and mechanisms to reinvigorate our national ST&I enterprise. These actions will become even more important in a time of diminishing resources.

In addition to these factors, the U.S. national security community faces even more profound challenges. The global deployment in civil society of new generations of advanced technologies, many of which can be dual use, will mean pervasive *technological surprise* and the appearance of new vectors for malicious action, such as commercial drones, the Internet of Things, and even misinformation and "fake news." The Trump administration, however, has a historic opportunity now to change our national trajectory by re-inventing the relationship between the Federal Government, the private sector, and international entities. In this regard, and because of its enormous resources, expertise, and its critical requirements, the Department of Defense and other national and homeland security agencies can potentially take the lead in developing a new paradigm to maintain our ST&I preeminence. In that way, the United States can maintain its *technological security* for the coming decades.

Notes

[1] *National Security Strategy of the United States of America* (Washington, DC: The White House, December 18, 2017, 20, available at <www.whitehouse.gov/wp-content/uploads/2017/12/NSS-Final-12-18-2017-0905-2.pdf>.

[2] By geostrategically, we imply that our national science, technology, and innovation (ST&I) strategies should account for the global landscape of geopolitical and other resource factors, of which foreign technology development is of increasing importance.

[3] For a holistic analysis of how emerging technologies may change the future global operational environment, see *The Operational Environment and the Changing Character of Future Warfare* (Fort Eustis, VA: U.S. Army Training and Doctrine Command, July 2017), available at <www.tradoc.army.mil/watch/OperationalEnvironment_ChangingCharacter_FutureWarfare.pdf>.

[4] For an overview, see Stephen Ezell, "Information and Communication Technologies and the New Globalization," Information Technology and Innovation Foundation, June 2017, available at <www.itif.org/publications/2017/06/26/information-and-communications-technologies-and-new-globalization>.

[5] For data and trends on technological acceleration, see Alison E. Berman and Jason Dorrier, "Technology Feels Like It's Accelerating Because It Actually Is," *Singularity Hub*, March 22, 2016, available at <https://singularityhub.com/2016/03/22/technology-feels-like-its-accelerating-because-it-actually-is/>.

[6] Nathan P. Freier, "Speed Kills: Enter an Age of Unbridled Hyperconnectivity," Strategic Studies Institute, June 2017, available at <https://ssi.armywarcollege.edu/index.cfm/articles/Speed-Kills/2017/06/09>.

[7] For examples, see Josh Constine, "Facebook Is Building Brain-Computer Interfaces for Typing and Skin Hearing," *TechCrunch.com*, April 2017, available at <https://techcrunch.com/2017/04/19/facebook-brain-interface/>.

[8] "The DoD and Synthetic Biology Milestones," *GlobalBiodefense.com*, April 12, 2016, available at <https://globalbiodefense.com/2016/04/12/dod-synthetic-biology-milestones/>.

[9] Keith Naughton, "Human Drivers Are Afraid to Hand the Wheel to Robots," *Bloomberg.com*, June 15, 2017, available at <www.bloomberg.com/news/articles/2017-06-15/autonomous-cars-biggest-roadblock-are-drivers-afraid-to-let-go>.

[10] See, for example, the Industrial Internet Consortium landing page available at <www.iiconsortium.org/>.

[11] Margaret E. Kosal, *Military Applications of Nanotechnology: Implications for Strategic Security* (Monterey, CA: U.S. Naval Postgraduate School Center for Contemporary Conflict, December 2014, available at <www.hsdl.org/?abstract&did=767053>.

[12] For example, see Rich Haridy, "Moon Express to Begin Commercially Harvesting Lunar Rocks in 2020," *NewAtlas.com*, July 2017, available at <https://newatlas.com/moon-express-2020-launch/50473/?utm_source=Gizmag+Subscribers&utm_campaign=bf165b25b5-UA-2235360-4&utm_medium=email&utm_term=0_65b67362bd-bf165b25b5-90180885>.

[<?>] *A 21st-Century Science, Technology, and Innovation Strategy for America's National Security* (Washington, DC: Committee on Homeland and National Security of the National Science and Technology Counsel, 2016), available at <www.defenseinnovationmarketplace.mil/resources/National_Security_ST_Strategy_2016_FINAL.PDF>.

[13] Data quoted from "Startup Act," Offices of Senator Jerry Moran and Mark Warner, available at <www.moran.senate.gov/public/_cache/files/5/5/55502dd4-0561-4e9e-ada1-6b277787a684/BBAD330F4DEE934CB73B852970AD75CA.startup-act-2017-one-pager.pdf>.

[14] Jeff Daniels, "Chinese Theft of Sensitive U.S. Military Technology is Still a 'Huge Problem,' Says Defense Analyst," *Yahoo Finance*, November 2017, available at <https://sg.finance.yahoo.com/news/chinese-theft-sensitive-us-military-032600386.html>.

[15] See, for example, Matthew Bey, "Between Geopolitics and Technology," *Stratfor.com*, September 27, 2016, available at <www.stratfor.com/weekly/between-geopolitics-and-technology>.

[16] Issues surrounding reform of the U.S. national security S&T enterprise have, in fact, been debated for many years; however, many of these problems still persist. For example, see William Berry et al., *Reform of the National Security Science and Technology Enterprise*, Defense and Technology Paper 56 (Washington, DC: Center for Technology and National Security Policy, October 2008), available at <http://ctnsp.dodlive.mil/2008/10/01/dtp-056-reform-of-the-national-security-science-and-technology-enterprise/>.

[17] A dedicated staff or committee lead could conceivably be appointed within the Office of Science and Technology Policy or the National Science and Technology Council.

[18] For example, see *Data and Analytics Innovation: Emerging Opportunities and Challenges* (Washington, DC: Government Accountability Office, September 2016), available at <www.gao.gov/assets/680/679903.pdf>.

[19] For an overview of how foresight methods and organizations could help the national security community plan for rapid technological change, see James Kadtke and Lin Wells, *Policy Challenges of Accelerating Technological Change*, Defense and Technology Paper 106 (Washington, DC: Center for Technology and National Security Policy, September 2014), section 2.1.1, available at <http://ctnsp.dodlive.mil/2014/09/12/dtp-106-policy-challenges-of-accelerating-technological-change-security-policy-and-strategy-implications-of-parallel-scientific-revolutions/>.

[<?>] For an overview of Government Strategic Investment initiatives, see Andrew Mara, *Maximizing the Return of Government Venture Capital Programs*, Defense and Technology Paper 71 (Washington, DC: Center for Technology and National Security Policy, January 2011), available at <http://ctnsp.dodlive.mil/2011/01/01/dh-071-maximizing-the-returns-of-government-venture-capital-programs/>.

[20] Geo-innovation would be a generalization of geo-economics, by incorporating the effects and distribution of technological capacity as a precursor to high-tech economic growth. See Kadtke and Wells, section 2.1.2.

[21] The natural Federal agency lead for science diplomacy would be the Office of the Science Advisor at the Department of State.

[22] See *The Operational Environment and the Changing Character of Future Warfare*.

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The Center for Technology and National Security Policy (CTNSP) within the Institute for National Strategic Studies helps national security decisionmakers and their staffs understand emerging impacts of technology and integrate them effectively into policies through research, teaching, and outreach. CTNSP supports the Department of Defense leadership and Congress while also encouraging whole-of-government and public-private collaboration.

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