60th IDA 1956 - 2016 | Proceedings

DSSG

Defense Science Study Group

30th 1986-2016 Anniversary Symposium

August 2016




IDA is the Institute for Defense Analyses, a non-profit corporation operating in the public interest.

IDA's three federally funded research and development centers provide objective analyses of national security issues and related national challenges, particularly those requiring extraordinary scientific and technical expertise.

Since 1956, IDA's basic mission has remained unchanged – bring the best scientific, technical, and analytic talent to bear on issues critical to U.S. national security, in a research environment free of commercial or shareholder interests where objectivity and the public interest are foremost.

To mark IDA's 60th anniversary, we are conducting a series of workshops and symposia that bring together IDA sponsors, researchers, experts inside and outside government, and other stakeholders to discuss issues of the day. These events focus on future national security challenges, reflecting on how past lessons and accomplishments help prepare us to deal with complex issues and environments we face going forward. This publication represents the proceedings of one of those events.

Acknowledgment

This is to acknowledge the support we received to make the DSSG 30th Anniversary Symposium a very successful one. First of all, a special thanks to Katherine Gliwa who was instrumental in identifying and planning all aspects of the symposium arrangements including execution of the event. Additionally, Brian Zuckerman and Rashida Nek did an outstanding job of capturing the essence of the presentations and discussion during the conference and creating the proceedings.




DEFENSE ADVANCED RESEARCH PROJECTS AGENCY
675 NORTH RANDOLPH STREET
ARLINGTON, VA 22203-2114

Bringing the transformative potential of research and technology to the most difficult security challenges facing our Nation is a responsibility and a privilege and depends on contributions from every sector of society.

For 30 years, the Defense Science Study Group has fostered critically important links between two of these sectors, the Defense Department and academia, educating top-tier engineering and science professors about defense systems, missions, and operations. Without public fanfare but with an unswerving commitment to keeping the United States at the forefront of the technological frontier, the DSSG—under the steady leadership of the Institute for Defense Analyses Science and Technology Division—has served as an excellent and important educational and cultural bridge, building and sustaining new communities of shared expertise dedicated to securing the Nation's future.

DARPA is proud to sponsor the DSSG and salutes all the individuals who have dedicated themselves over the decades to supporting the organization and the partnerships it has catalyzed.

Arati Prabhakar
Director

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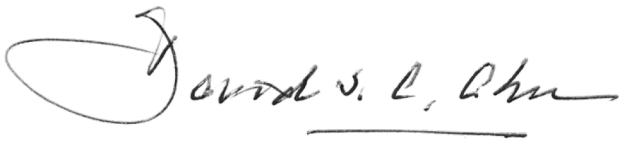
IDA | David S. C. Chu
President

For a generation now, it's been IDA's privilege to serve as the steward for the Defense Science Study Group. Initiated to encourage interest in national security issues among academic scientists, it's spawned over 200 alumni, many of whom have indeed stepped forward to assist the federal establishment.

The DSSG 30th anniversary coincides with IDA's 60th. DARPA's invitation to organize the DSSG is consistent with IDA's origins, and its role coupling academic engagement to national security challenges. In 1955, Secretary of Defense Charles Wilson asked the President of the Massachusetts Institute of Technology, Dr. James Killian, to start IDA as an independent, civilian, non-profit overseen initially by a consortium of universities (originally, MIT, the California Institute of Technology, Case Western Reserve, Stanford, and Tulane, with the University of California at Berkeley, Chicago, Columbia, Illinois, Michigan, Penn, and Princeton added later). Explicit university oversight of IDA ended in 1968, but IDA's ties to the university community continues with a significant element of its Board affiliated with academia.

As the United States confronts the security challenges of the early 21st century, and as we think about the future role of institutions like ours, we thought it timely with this Symposium to reflect on how science and technology have contributed to national security success, based on the experience of the DSSG alumni—and others. But more important, the Symposium dialogue opens the door on a conversation about the contributions science and technology can contribute to resolving the new challenges we face.

We encourage all to use these Proceedings as a stimulus to their thinking in this regard—and to share their reactions with us.



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The 30th Defense Science Study Group Anniversary Symposium on National Security was a most interesting and informative two days of presentations and discussion on the role of science and technology in safeguarding our nation's security. We are delighted to present the Proceedings of that two-day Symposium.

First and foremost, I am especially grateful to DARPA not only for their endorsement of this Symposium but also for their continued support of the DSSG program for the past 30 years. I recall my meeting over 30 years ago with then Deputy Director of DARPA Larry Lynn. I mentioned to him my frustration at attempting to involve young academic scientists in the many technical challenges facing our defense community. This apathy was the result of the lingering experience of Vietnam and the height of the Cold War. I proposed the idea of a special fellowship program to objectively introduce our emerging academic leaders to the people involved in defending our nation and to the complex challenges they confront. Larry Lynn liked the idea and decided to try the "experiment."

You may recall that in the mid-1980s, the White House and the Department of Defense had prioritized the development of the Strategic Defense Initiative missile defense program, or "Star Wars." At the time, the program was quite controversial and a major reason for the distrust by academics on defense related matters. At our first organizational meeting with the new members in December of 1985, I asked the group to have an executive session and determine the "requirements" for their participation. They only had two: first that I rename the program from what I had originally called the "Young Scientists Program" to the "Defense Science Study Group" and, more seriously, that they never wanted to meet anyone associated with Star Wars, that they never be presented with anything related to Star Wars, and that we never accept any funding from Star Wars. I agreed to both. And needless to say the experiment worked. Since that time DSSG has enjoyed the support of 11 DARPA Directors.

The experiment worked for three basic reasons:

- First, the 15 members of the initial class, when approached, were open minded enough and willing to participate and to help design the program with me. It was truly a collaborative effort.

- Second my mentor and the then president of IDA General Andrew Goodpaster told me that I would need help guiding the program, mentoring the members, and opening doors. He recruited a group of senior distinguished members of the defense community to assist me; they became the Mentors. These Mentors included senior retired Flag Officers from each of the Services as well as other distinguished members of the national security community including Gen. Lew Allen, Adm. Ike Kidd, Sol Buchsbaum, Johnnie Foster, Gene Fubini, and Herb York to name just a few.

- And, finally, the Department of Defense at the most senior levels recognized the future value of such a program and, in addition to the DARPA sponsorship, led the way in their willingness to expose the group to the many dimensions of our national security complex.

And so what are the results of the 30 years of the DSSG experience?

The program has had 15 different classes to date, produced 226 members and alumni from 67 of the nation's top research universities, and enjoyed great diversity with represented disciplines ranging from physics, engineering, and mathematics to psychology and medicine. The program over the years has enjoyed tremendous support from both the university and national security communities. It has led to new generations of scientists and engineers becoming involved in national security in a variety of ways:

- The members have served in more than 200 different government-related science advisory roles and government leadership positions.
- The participation rate on defense-related advisory boards and task forces is nearly 50 percent and growing.
- Members have filled numerous senior government positions in DoD (including eight in DARPA), DHS, DOE, and the White House.
- Many are now pursuing research focused on national security challenges including more than 50 research projects for DARPA.
- And all members have provided an educated voice on campus regarding the institutions and people responsible for the defense of our country.

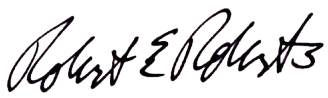
Looking back, it's remarkable how dramatically the world has changed since the DSSG began, both in terms of national security and in terms of science. In 1986, the relationship between the United States and the Soviet Union was the primary national security challenge we faced. While the dialog between President Reagan and Secretary Gorbachev in Reykjavik, Iceland, rekindled arms limitation discussions, deterrence depended on immense stockpiles of nuclear weapons. Physical sciences and engineering were the primary disciplines brought to bear on defense-related challenges.

Today, we face a far broader array of national security threats and challenges. While we still have Russia and nuclear weapons, we're also concerned with other state actors: China, countries in the Middle East, an array of non-state actors – including terrorist groups like ISIS, Hezbollah, and Al Qaeda –drug cartels, and hackers in cyberspace. Even the environment around us and Earth's changing climate influence the security of our nation. Because of this, it is even more important today than it was 30 years ago to introduce new generations of emerging leaders across the entire spectrum of science and technology to these pressing defense challenges and for them to be engaged with the national security community.

The other dramatic change in our security landscape is how technology has changed. In 1986, there was no internet, and cybersecurity wasn't in our vocabulary. Now there is a greater mix of civil and military technologies and systems today than ever before – GPS, the internet, use of space, cyber and infrastructure security, global warming, and so forth. Because of this diversity of technologies, it is even more important to introduce and involve new generations of emerging leaders of science and technology to these pressing problems.

Our stated purpose of the Symposium was to engage and educate current and past DSSG members and DoD officials including DARPA representatives in a discussion of contemporary national security topics. The topics ranged across defense-related science and technology issues and perspectives, the role of academia in national security, and using technology to create strategic advantage for the Nation and to establish new collaborative partnerships to meet emerging national security challenges.

In recognition of these DSSG achievements and the expanding role of academia in addressing our multi-faceted national security challenges, we celebrated the 30th Anniversary DSSG National Security Symposium and proudly present these Proceedings.



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Symposium Day 1

Symposium Rationale and Welcoming Remarks

Dr. David Chu, the President of the Institute for Defense Analyses (IDA), welcomed the DSSG members and mentors, and described the dual purposes of the symposium. First, the symposium has been convened to celebrate the 30th anniversary of the DSSG. Second, the symposium is intended to initiate a dialogue regarding how science and technology can contribute to the United States' national security posture in the years ahead. Our security posture stands at a critical juncture, and classic military solutions that have worked in the past may not in the future. The U.S. Department of Defense (DoD) is searching for answers, and a goal of this symposium is to initiate a dialogue and identify technological possibilities to address some of these issues.

Dr. Chu connected the DSSG's 30th anniversary to IDA's own 60th anniversary. IDA arose from a similar impulse – because the government was having difficulty gaining academic support for the then Weapons Systems Evaluation Group (WSEG). Secretary of Defense Wilson asked the Massachusetts Institute of Technology organize a board of leading universities to oversee the WSEG, which led eventually to the formation of IDA. It is interesting that DARPA inaugurated the DSSG in 1985 as that generation's way to bring the academic community and national security apparatus back together again.

Dr. Roberts also welcomed the DSSG members and mentors, thanked the Defense Advanced Research Projects Agency (DARPA) for their support for the DSSG over the last 30 years, and thanked the various DSSG mentors that have contributed to the professional development of DSSG members. He mentioned some of the successes of the DSSG:

- The DSSG has engaged 226 members and alumni from 67 of the top research universities in the United States, with broad disciplinary diversity.
- Of the DSSG graduates, 50% have become involved in 10 defense and intelligence advisory boards.
- Graduates have filled numerous senior positions in the DoD (including at DARPA), the U.S. Department of Homeland Security (DHS), the U.S. Department of Energy (DOE), and the White House.
- Many graduates pursue research on defense challenges and are ambassadors on campus for the value and importance of national security-related research.

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Symposium Discussions

S&T Perspectives in National Security Panel

Dr. Craig Fields, the panel moderator, used five framing questions to initiate discussion. Question 1: What single advance in science and technology (S&T) do you anticipate for 2026 that will have the greatest benefit for national security? Answers included:

- *Predictive analytics*. Leveraging big data analytics to enable us to have high confidence in predictive behavior, especially with respect to terrorism and radicalization.
- *Assured information*. Need for technologies that will enable us to trust information (e.g., positioning, navigation, and timing).
- *Virtual coaching and training*. The convergence of wearable computing devices, plus trusted information and long-life battery power, will fundamentally transform training and interleave it seamlessly with operations. Applications to non-defense technical training will likely arise as well.
- *Three-dimensional (3-D) modeling and printing*. The technology will change design capability, reduce production times for critical parts, and decrease sustainment costs.
- *Intersection of neuroscience and physical sciences through the BRAIN Initiative*. The goal of this initiative is to develop a set of tools that will allow us to study the brain in action, providing fundamental understanding about how brain encodes and processes information, improving diagnosis/prevention of diseases, and giving insights into next generation of computers.
- *Intelligent, swarming, machines*. As manufacturing and data costs get lower, drone use will expand substantially, especially coupled with learning from biology about swarming behavior.
- *Artificial intelligence (AI)*. A DARPA symposium suggested that history will show that the Internet wasn't the best thing that came out of DARPA; AI was.

Other points made included:

- Using new technologies and social sciences will aid in short-term prevention and long-term understanding of terrorism.

Question 2: What incredibly promising technology today will fizzle out by 2026? Answers included:

- *"Commonality" and "jointness."* Participants expect that 3-D printing and design will once again allow for tailored systems.
- *Stealth*. The cost effectiveness of stealth technology has been diminished by lower-cost counter-stealth technologies and low-cost unmanned platforms.
- *Kinetic warfighting technologies*. While today we spend billions on planes, ships, missiles, and tanks, future conflict will rely more on non-kinetic means.
- *The nuclear triad*. In the next decade, there will be less need for all three dimensions of the current land-air-sea distribution of nuclear weapons.
- *Hypersonics*. Participants considered hypersonic flight to be a technological solution searching for an application area or problem.

Other points made included:

- There is likely less reliance on Silicon Valley as the locus of innovation in the United States. The venture capital world is starting to look elsewhere across the United States and worldwide.
- The effectiveness of ITAR and export controls is diminishing. In a global economy, new knowledge and dual-use technologies will diffuse regardless of U.S. controls.
- The U.S. and defense needs rely on the consistent functioning of a global supply chain, which poses risks.
- Given cyber-risk and insider threats, the Department of Defense will need different mechanisms and methodologies for testing highly reliable and relied-upon systems.

Question 3: National security is increasingly focused on public opinion (U.S., worldwide, ally, adversary). How can the U.S. government properly shape public opinion consistent with American values? Answers included:

- We as scientists, need to be more transparent and articulate at a national level about our primary objectives, what we will or won't do.
- The U.S. public, when spoken to intelligently, will rise to the occasion.
- In the U.S., we need more training around critical thinking – 'look-up' culture given the rise of the Internet, may cloud critical judgment. There is limited public understanding of how science functions and of the nature of scientific controversy and consensus.
- The Administration is working to diminish gaps between median public sector performance and private sector performance. Some approaches that have been taken (e.g., 18F, the U.S. digital service) appear to be successful with respect to information technologies, building citizen-facing digital services using a modern technology stack and agile/human-centered design.
- We need to improve our public communication skills (e.g., Alan Alda Institute* as a training mechanism).
- We need to increase the importance of evidence-based policy-making and allocate more funds based on evaluation. The Millennium Challenge Goals represent an example. We can project a desirable future, get consensus on it, and invest based on it.
- The U.S. needs to understand other cultures before we begin operations. We rush into countries and impose our values on totally different cultures. We need to understand whom they trust, and how they receive information. We need to inform our information dissemination.
- We must make greater use of the diversity of cultures inside the U.S. to inform foreign policy.

Question 4: The ecology of S&T relative to national security has changed. There is no longer a linear path from U.S. government research through knowledge generation to applications. Greater roles are being played by private sector funding and non-U.S. S&T. Any insights? Answers included:

- Spin-on and spin-off are both beneficial. DoD has invested in GPS and lasers, which are being used commercially. Fundamental research (6.1) money that DoD spends does basic research that is commercially beneficial as well. Spin-on technologies also need to be more robust and reliable for defense use.
- Both spin-off and spin-on are important. Because we have been fighting wars for so long, there has been less 6.1, and more applied research. There have been fewer spin-offs, and spin-on has been more interesting.

* Alan Alda Center for Communicating Science® | Stony Brook http://www.centerforcommunicatingscience.org/

- It takes time for spin-off and spin-on to work.
- Institutional innovation is as important as technological innovation. There needs to be the right impedance match between DoD and startups. DoD pilots are promising. The U.S. has a history of institutional innovation (land-grant universities, agricultural extension, National Academies).
- Large teams at DoD do root-cause analysis when things go wrong. No one at DoD has the authority, responsibility, and mission to spread things that are working.
- The National Security Agency (NSA) incubation cell links front-line employees with researchers, who get a small amount of time to develop prototypes. If an approach is validated, NSA invests more funding to expand and develop the approach.

Question 5: The Internet seemed like a good idea at the time, but it has enabled dangerous behavior as well. How do we balance the good with the bad?

- Three waves of computing started with using computing for simulation, then for communication, now increasingly now for embodiment. If we are to have closer coupling between the physical and digital world, we need to do better with reliability and security.
- The Internet has provided significant connectivity worldwide. It's a worldwide educator.
- People with different ideologies will always exploit opportunities.
- The focus has to be on trusted computing infrastructure and software.
- There is a need for Internet resilience, because the Internet will never be fully secure. We need to be smart about security, but we need to assume attacks will occur and know how to recover in real time. Because changing or replacing the Internet doesn't make sense, it follows that there needs to be a "maturity model" for the Internet.

Breakthrough Technologies for National Security

Dr. Arati Prabhakar, DARPA's Director, began by restating DARPA's history and mission ("preventing technological surprise by inventing it ourselves") and gave two examples of current activities.

- *Infectious disease*. The world needs more rapid development of diagnostics, preventive strategies, and therapeutics to nip emerging infectious disease in the bud.
- *Artificial intelligence (AI)*. DARPA has invested historically in second-wave AI based on machine learning whereby systems learn statistical models of specific problems using big data. Examples of current approaches include:
  - Real-time translation/speech recognition
  - Real-time adaptive jamming
  - Automated cyber defense
  - Unmanned ships for long-duration missions.

DARPA is also investing in third-wave AI – contextual adaptation. Systems construct explanatory models, communicate with people, learn and reason in new situations. Third-wave systems will be built on models that can learn, explain themselves to humans, and generate trust.

Discussion during the Q&A session with Dr. Prabhakar included:

- DARPA's work on the vulnerabilities inherent in the technologies they develop.
- DARPA efforts in using social behavior to prevent radicalization.

- Concerns regarding pervasive 3-D printing with multiple materials, whereby physical security becomes a cyber-security question.
- Differences between DARPA's activities on infectious disease and AI and commercial sector efforts.

Role of Academia in National Security Panel

Discussion was framed in response to panel chair Dr. Steven Koonin's questions to the panel:

Q: How did DSSG experience motivate you and prepare you for DoD advisory roles?

- The DSSG helped to open my eyes, and likely those of other academics, to two essential factors. First, the Department of Defense has to operate with tremendous constraints placed on it, which go far beyond those that apply to the commercial sector or other domains. Understanding those constraints (legal/policy, operational factors that involve transitioning new technologies into a legacy of systems) was essential for understanding what advice is most useful in this environment.
- Second, academics by the nature of their profession are often the "smartest people in the room" within their specific field – they are very comfortable in discussing the science and technology associated with their field. However, once you enter the defense science advisory world, you are instead asked to hear about and speak on a much broader range of topics, most of which are well outside your own area of primary expertise. It is essential to understand that what you really bring to the table is a deeply analytical way of thinking about problems, not just those in your own technical area. DSSG helps its participants understand that and become comfortable with it, especially through the "think piece" projects. These projects help academics to bring their analytical skills to broader DoD challenges.

Q: What attracted you to get involved in DSSG? What has been the greatest reward?

- DSSG had a profound effect on my life and career. It inspired me to expand on my basic research to consider the implications of my research and relevant applications for the DoD. That in turn allowed me to take on a number of defense science advisory roles. My resulting increased awareness of DoD problems certainly broadened my perspectives and, later, my research portfolio; learning about these issues also allowed me to bring unclassified technical issues into the classroom.

Q: What kind of institutional and cultural landmines exist in bringing together academia, government, and industry to conduct large-scale research?

- While DoD-relevant programs and the research to address DoD challenges are typically interdisciplinary, academia remains largely siloed – although this has been changing in recent years.
- Working collaboratively with industry can be very stimulating, but it is often hard, especially if the company imposes restrictions such as ITAR [International Trafficking in Arms Regulations] or severe limitations on research publication under a funded contract. In addition, timescales for DoD and industry "applied" research are different from those in the university/basic research arena; further, the defense industry has development and operations timescales that are different from health sciences industries.
- Universities are largely focused on faculty-inspired research efforts, and typically are not as conducive to the kinds of large-scale, top-down, concerted efforts that may be needed.

- University research is also largely based on grants, and often doesn't respond well to contract-driven research with its emphasis on deliverables and schedule.
- Classification and the need for security clearances present a significant obstacle, but this point is often overstated. The greater issue is helping university faculty understand how they can engage with DoD.
- DSSG plays a key role in building that kind of awareness and engagement with DoD, but there is a need for DSSG to reach a larger scale – 200 investigators having participated in the DSSG over the past 30 years is impressive, but is small relative to the scale of the academic enterprise in the United States.

Luncheon Speaker

The Honorable Frank Kendall, the Under Secretary of Defense for Acquisition, Technology, and Logistics (AT&L), discussed DoD innovation initiatives, including DARPA, the Defense Innovation Initiative, making use of CIA's In-Q-Tel, and Force of the Future to increase permeability of DoD to new technologies.

Mr. Kendall also discussed DoD's current threat-driven budget. In 1970s, we were focused on the Soviet Union and the Cold War; we worried about technological superiority because of the nature of the adversary. The current budget lists five threats:

1. China } Great powers, advanced military equipment with
2. Russia } eye toward challenging the U.S.
3. Iran } Regional powers
4. North Korea }
5. Non-state actors/terrorists/ISIL

China is building layered capabilities to control escalation, which starts with cyber/electronic warfare, space control capabilities, weapons designed to defeat aircraft carriers, forward airfields. The U.S. is very dependent on small number of high-value assets/targets. China is building capabilities intended to defeat those. China emulates what we're doing with precision munitions. Russia has recognized an economic and technological imbalance and is relying on nuclear weapons.

Mr. Kendall also discussed the "third offset" strategy. The *first offset* was tactical nuclear weapons to offset Soviet tanks. The *second offset* strategy was precision munitions/strike at a distance. The *third offset* strategy includes AI and autonomy, distributed capabilities, and operating from greater range. The purpose of the third offset will be to protect high-value military assets, assuming a future with a leveled technological playing field; a globalized technology space; and greater reliance on commercial off-the-shelf (COTS) systems. This approach is still a work in progress. DoD has placed demonstration programs in the fiscal year 2017 budget to buy technological options.

Mr. Kendall also noted that warfare is changing. It's been a very long time since there has been a peer competitor conflict, and many U.S. capabilities (e.g., information technology, space systems, and missile systems) have never been tested in practice. This makes the results of a conflict more uncertain.

Points discussed during the question and answer session included:

- Progress to date of innovative procurement approaches such as In-Q-Tel and Defense Innovation Unit Experimental (DIUX)
- Balance among early-stage research, applied research, demonstration, and development accounts in the DoD research portfolio
- Supply-chain issues related to rare-earth minerals
- The future role of the DoD intramural laboratories
- The future DoD posture relative to terrorism-related threats.

Creating a Clean and Secure Energy Future

Dr. Franklin Orr, Under Secretary for Science and Energy at the Department of Energy, spoke regarding the role of technology in creating a secure and clean energy future. He began his talk by reviewing the many lines of evidence that demonstrate that the Earth's climate is changing and that the change is being induced by human activities. He then described the three-level energy challenge that the United States faces:

1. *Economic security*. The U.S. needs cost-efficient and cost-effective systems for energy generation and distribution.
2. *Environmental security*. The U.S. needs lower emissions of greenhouse gases (GHG) and decreased emissions of other pollutants.
3. *Energy security*. The U.S. needs multiple supply options that are robust and resilient to minimize the risk of disruptions.

Dr. Orr mentioned that engineering improvements, new manufacturing approaches, and improved materials are reducing the costs of system design and installation. This is vital because capital and operating costs determine how technologies compete to determine the nation's energy mix. He cited data showing dramatic changes in some technology costs in the last five years (wind costs down 40% since 2008, photovoltaic technologies reduced by 50-60%, and light-emitting diodes by 90%).

Dr. Orr then summarized the results of the most recent DOE Quadrennial Technology review, which assesses energy technologies and research opportunities.

Comments regarding the power grid included:

- The future electric grid will be more flexible and agile than the current one. It will have an increased number of sensors, faster computing for the purpose of state identification, and more flexible control systems.
- The future electric grid will be able to accommodate renewables and distributed energy generation, and will use storage and shifting load to balance supply and demand.
- The future electric grid will be designed and operated as a system of systems rather than to optimize each individual component without consideration of the whole.

Comments regarding energy storage included:

- Batteries are an active area of research. New chemistries are being explored.
- Utilities are beginning experiments at grid scale.

He commented on clean electric power efforts, technology by technology.

- *Carbon capture and storage*. It is technically feasible to capture carbon dioxide, store it below the Earth's surface, and have it stay there. But the technology is extremely costly; the cost lies in chemical separation and carbon capture. The technology has been deployed at the scale of megawatt-sized power plants, and at natural gas plants.
- *Nuclear*. Nuclear energy represents 19% of U.S. electrical generation today. New research and technology efforts include extending the life of existing reactors, developing small modular reactors, developing high temperature gas-cooled reactors, and developing fast-spectrum reactors. The industry still requires attention to concerns regarding waste disposal. The high cost of siting and building nuclear power plants remains a concern.
- *Wind*. Wind represents 4% of U.S. electrical generation today and is cost-competitive in some locations. The United States still needs to be able to increase capacity, by optimizing turbine designs, accessing the best locations for wind generation, and building transmission lines to connect wind energy sources to the electric grid. With these enhancements, wind might provide 35% of U.S. electricity generation by 2050.
- *Solar*. Solar technologies are increasing in efficiency, and are approaching 30-40% energy conversion efficiencies for relatively high cost multijunction cells. New, low-cost technologies such as perovskites are also increasing their conversion efficiencies toward the point where they might become viable.

Dr. Orr's comments on increasing the efficiency of building systems and technologies included:

- Buildings currently use 40% of energy and 75% of electricity. But it is feasible to reduce that energy use by 20-35%. Improved windows, lighting systems, and heating, ventilation, and air conditioning as part of more efficient building designs will all contribute to savings.
- Transportation technologies will benefit from improved combustion engines, lightweighting, and better batteries. Sales of electric vehicles are starting to rise, albeit from a low baseline.

Dr. Orr discussed the potential benefits of advanced manufacturing from the standpoint of energy efficiency (as distinct from its benefits associated with reduced engineering production and design time. He cited data showing that 3-D printing may reduce material use and therefore the energy embodied in finished products.

He commented on the role of fundamental scientific research at DOE facilities as an enabler of energy research.

- Understanding and controlling matter at the atomic scale builds on DOE laboratory resources (X-ray light sources, Spallation Neutron Source, Nanoscale Science Research Centers).
- Modeling and simulation of complex phenomena relies on DOE petascale and exascale computing resources.

Finally, Dr. Orr commented on the international dimension of reducing energy use and implications for decreasing carbon dioxide emissions:

- China has now committed to reach its peak of CO_2-equivalent emissions by 2030, though best efforts will be made to peak earlier. China has also committed to reduce

greenhouse gas emissions per unit of Gross Domestic Product (GDP) by 60-65% from 2005 levels, and to work toward generating 20% of its primary energy from non-fossil resources.
- The United States has committed to reduce greenhouse gas emissions by 26-28% below 2005 emissions by 2025. The Clean Power Plan for reductions in CO_2 emissions from electric power generation is one component of that reduction.
- One hundred eighty-seven countries (accounting for 95% of world greenhouse gas emissions and 98% of population) made Nationally Determined Contributions as part of the Paris Agreement.
- Twenty countries announced plans to seek a doubling of public-sector energy R&D over the next five years. A coalition of philanthropists has also promised to invest in early-stage technology development in low-carbon energy technologies.

Homeland Security Challenges

The Honorable Tom Ridge, former governor of Pennsylvania and the first Secretary of Homeland Security, ended the symposium's first day of deliberations by describing challenges associated with homeland security. He began his remarks by stating that the mission of the DSSG may be as important as or more important than it has ever been, because of global changes:

- The world is more interconnected and interdependent – and this interdependency is likely to accelerate.
- The threat surface has expanded in the physical and digital world. Oceans and land borders that once provided security have been bridged by technological advances.
- While there have been technological advances, they are double-edged, creating security risks as well as opportunities.

He concluded his overall assessment by stating that in the 21st century, social, economic, and political opportunity abound, but there's a higher risk of potential conflict. Secretary Ridge highlighted two growing conditions. First is the global scourge of terrorism. Terrorism is increasingly global (i.e., not just in Afghanistan and Pakistan as was thought after 9/11) and involves a wider number of groups (i.e., not just Al Qaeda). Islamist terrorism currently kills more Muslims than non-Muslims, and the West needs to build bridges to Islamic communities, rather than walls. Nevertheless, terrorism is a tactic, and it is necessary to wage war against those who use it rather than against entire communities or groups. The second condition he highlighted is what he called the "digital forevermore." He mentioned that it is expected that 50 billion devices will be connected to the Internet by 2020. DSSG and the S&T community writ large therefore will need to muster scientific skill to alleviate these two burdens. Moreover, Secretary Ridge expects that these two conditions will merge; he expects terrorists to join state actors (and other non-state actors) to become active in the cyber-domain. Nation-states will continue to use cyber-space as a geostrategic weapon. For example, Russian, Iranian, and Chinese governments have been using cyber-attacks, and these approaches were considered to have been validated by the Stuxnet cyber-attack on Iranian nuclear facilities. ISIS has been trying to steal information about U.S. leaders in the hope of spurring physical attacks. He noted that the barriers to entry into digital warfare are low and consequences from state actors have been are limited.

Secretary Ridge concluded his remarks by raising four challenges for consideration:

- *Balance between privacy/civil liberties and security*. He noted that DHS was the first department to have a Congressionally mandated privacy officer and that DHS's first responsibility was to preserve liberties. Nevertheless, questions regarding the balance remain. How can the U.S. remain open and free if adversaries leverage those freedoms? How do we secure global commerce in a diverse global marketplace dependent on its digital backbone?
- *Educating organizational leadership on technological issues*. He noted that there often is a breakdown in communications between those who lead organizations and those who manage technologies and operations. Secretary Ridge called upon DSSG members to consider the policy implications that accompany the technologies they develop and to work with and educate policy makers as they are developed. It is unfortunate to have a debate in the middle of a crisis as to whether a technology is appropriate.
- *Disconnects between pace of technological change and organizational decision-making*. He argued that technology and science will always move faster than legislators or corporate managers, which poses a problem. As a result, the notion that in the 21st century the United States can continue buying technologies in the same way is fruitless. Enemies may gain advantage by gap between technology development and U.S. technology acquisition policies.
- *Biodefense*. He argued that the United States does not pay enough attention to biodefense. It remains a major vulnerability today. Detection capabilities are limited and rapid manufacturing capabilities for therapeutics and vaccines almost nonexistent.

Points raised during the question-and-answer period included:

- Whether it is necessary to rebalance freedom and liberty in the service of enhanced security
- Increasing public trust in government and other U.S. institutions
- Managing risks associated with cultural differences
- The risk of terrorism in the context of other threats.

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Symposium Day 2

Symposium Discussions

Technology for Strategic Advantage Panel

Dr. David Chu, the panel moderator, conducted the session in question-and-answer format in dialogue with the panelists.

Question: Where have we succeeded in the past in using technology for strategic advantage, and where have we stumbled? Discussion included:

- Creating a strategic advantage from technology is a narrow view of the problem. In situations where the United States created strategic advantage, there were four enablers: 1) developing innovative mission applications that require new technologies; 2) technology advancement itself; 3) experimentation to identify how best to make use of new technologies in the context of mission applications; and 4) systems integration, which requires an impedance match across the other three enablers.
- Strategic advantage arose from incremental advances, made in combination, rather than from revolutionary breakthroughs. There were unforeseen elements in successful programs.
- Successful programs require a cadre of trained technical personnel (across industry, academia, and government) to address problems as they arise.
- Examples were given from the "second offset," which incorporated precision-guided munitions; stealth; long-range intelligence, surveillance, and reconnaissance (ISR); and positioning, navigation and timing (PNT).
  - The overall challenges and capability gaps were that lethality per sortie was low during the Vietnam War and that aircraft could not operate successfully at night, in poor weather, or inside the envelope of advanced Soviet surface-to-air missile systems.
  - The need for development of precision-guided missiles was highlighted by the difficulty in destroying key bridges in North Vietnam. With continuing research and development, solutions progressed from the pilot-guided Bullpup to electro-optical, infrared, and GPS guided with continuous improvement in accuracy and growth in around-the-clock, night, and all-weather precision attack capability.
  - The development of synthetic aperture radar was originally undertaken to find space-based solutions for seeing through cloud cover over denied areas. Multiple experimental units were built and tested in ground and aircraft platforms in order to identify the technology's potential capabilities and uses. This work also became the foundation for J-STARS.
  - Development of stealth technology also required substantial experimentation to identify technology drivers and limitations.
  - When these technologies were first considered in the 1970s, there was no planning for the end state achieved during the 1990s and the phrase "second offset" was not familiar to those developing the technologies at that time.
  - Agility in acquisitions is important. It is not possible to define requirements for warfare beyond 10-15 years in the future. Agility allows DoD both to be able to incorporate technologies as they mature and to change purchasing strategies as the uses of technologies are better understood. Example was given of the F-117 fighter, originally

considered to be useful for surface-to-air missile (SAM) suppression and requiring only two dedicated squadrons, but as the aircraft's potential was realized, numbers were increased.

Question: How hard is it to make a technology operational? What kinds of resistance gets encountered? Points made included:

- If the motivation is a recognized operational need or capability, anything that fills that capability is welcomed.
- New technologies that don't fill a recognized need may not be welcomed. Stealth was identified as an example. DARPA offered the Air Force stealth technology 5-6 years before they became excited about it. It took the Soviets' fielding the SA-5 surface-to-air missile system, which upset our fundamental strategy for dealing with the Warsaw Pact, to lead to stealth's rapid acceptance and approval.
- The "muscle tone" for conducting experimentation and demonstration is important in making new technologies operational. There is concern that fundamental capacities in this regard may not be sufficient today.
- In 2013, DoD started its 2030 long-range technology development planning process; the appetite for that kind of thinking was enormous, reflecting concerns that we have about the United States' future power position and posture.
- Currently, there has been a re-emergence of a set of symmetries between the United States and other countries in military capabilities that makes defense planners uncomfortable. The United States has had asymmetric advantage due to "second offset" that has allowed for the projection of power globally with limited forces and low losses. For last 15 years we've been engaged in counterterrorism campaigns globally, and now we look out to see a world where we are not the sole possessor of precision weaponry.

Question: We've disestablished Joint Forces Command, which previously served as a home for demonstration and experimentation. Who should be doing this? Points made included:

- Experimentation is required at multiple levels.
- Experimentation needs to be done under field conditions in addition to demonstration/proof-of-concept conditions.
- The spirit of experimentation requires acceptance of failure.
- The pace of experimentation and upgrading is linked to the evolution of the technology domain; electronic warfare systems need a more rapid upgrade cycle than the long-range strategic bombers that use them.
- Major acquisition programs often occur over 20-plus-year time scales; we need entry ramps for new technologies and upgrade cycles or block changes that relate to the cadence of the mission.
- Our competitors and adversaries are looking at best practices from the second offset and are looking at weaknesses and opportunities to exploit. Experimentation will be required to continue getting best use out of existing technologies while new ones are being brought to fruition.

Question: Retrospective looks usually highlight successes. Where did interesting failures occur? Points discussed were:

- Most interesting failures come from trying to leap the chasm rather than through incremental advance.
  - The F-22 is a case of trying to introduce too much technology too fast. As a result, development took twice as long and cost twice as much as expected.
  - The F-111 is a case of developing operational concept without doing experimentation. The F-111 concept of operations originally included close air support with the aircraft based near the battlefield rather than at prepared airbases; operational experimentation showed that it was not practical to load fuel and ordnance onto the plane under field conditions.
  - The F-117 is an example of where the modeling and simulation underlying development didn't match real-world conditions. Initial tests of the F-117's capabilities showed no correlation with simulations; it took considerable experimentation before the models were sufficiently sophisticated to be useful in predicting and simulating actual performance. Models are useful for interpolation, but not extrapolation.
- The greatest technology successes have occurred by fielding an initially militarily useful capability that solved a problem, followed by regular incremental improvement. The F-16 and M-1 tank are examples of core technologies developed along this path.

Question: What worries you most about DoD's current approach? Discussion points included:

- There's a worry about DoD's ability to respond to disruption. Incremental improvements work well where adversaries are on a static path. It is hard to identify when there are step functions that render existing systems obsolete.
- DoD should have more modest expectations for the first increment of military capability in any program. The goal should be to field an initial capability in a reasonable time (5-7 years). Incremental improvements in follow-on models can best meet future needs.
- DoD does poorly when trying to introduce breakthrough technologies.
- The inability to rely on capabilities such as armor, stealth, and manned aircraft in the face of symmetry in precision weaponry is a concern as is the challenge to the DoD S&T base.
- DoD's laboratory capabilities may not be sufficient, and it is not clear that they have the right people.
- Similar concerns were expressed with regard to acquisition capabilities. Panelists noted that DoD is competing for S&T talent in an international marketplace.
- There's a compression in the time between U.S. fielding a capability and others' ability to do so; in some cases, others are getting technology first. Foreign companies are more aggressive in exploiting technologies than we are.
- Finally, there's a concern that the U.S. government as a whole is not supporting enough fundamental research.

Question: How does DoD decide what not to do? Points included:

- That's not the right question. DoD needs to figure out how to build the best fighting force possible given the resources available. *That* determines priorities.
- DoD needs to challenge itself and aggressively consider alternatives. The 2030 technology planning process challenged assumptions and identified requirements for $18 billion in critical modernization efforts and $6 billion in new efforts.

Points raised during the question and answer session included:

- The sufficiency of the DoD human resources process and the use of experimental authorities
- Supply chain concerns in defense procurement
- Considerations regarding economic espionage and cyber-threats, and the need for enhanced public-private partnerships
- The potential re-emergence of tactical nuclear weapons as part of adversaries' own offset strategies
- The pace of technology maturation.

The Role of Academics in National Issues

Dr. Thomas Rosenbaum, the president of the California Institute of Technology, spoke on the question of how academics can get involved in national issues and how the interaction with DoD can be rewarded or incentivized academically. Dr. Rosenbaum made four fundamental points regarding the academic role:

- *Primacy of principle*. Dr. Rosenbaum mentioned that if areas of research are important, it is important for academia to work on it; he gave the example of the University of Chicago supporting nuclear power research at Argonne National Laboratory. Tenure gives academics the freedom to say what they believe. At the same time, academia needs to accept the responsibility to contribute talent to issues of national importance and to recognize that, even with enlightened sponsors, there can be value conflicts.
- *Fearlessness and ambition*. Dr. Rosenbaum mentioned that academia is a place to have ideas and to propose them regardless of risks or difficulties. He gave the example of the recent discovery of gravity waves through the Laser Interferometer Gravitational-Wave Observatory (LIGO). This project, the largest in the National Science Foundation's history, was seeded originally using California Institute of Technology funds for interferometer testing. The University of California system and the California Institute of Technology are currently developing plans for the next generation of 30-meter optical telescopes, in advance of substantive U.S. government support.
- *Perspective*. Academia needs to advocate for the value of fundamental research and knowledge even where there are no obvious societal ramifications. He cited the examples of Robert Wilson's defense of Fermilab and Danielle Allen's comments on the importance of teaching Thucydides in the immediate aftermath of 9/11.
- *People*. Academics' long-term contribution comes in training people. We send our students out to contribute to the future of this country. DSSG is valuable in that it leads participants to appreciate the incredible talent that is out there in our military, particularly the flag officers.

Additional points discussed during the question and answer period included:

- The value of major research instrumentation
- The role of universities in fostering critical thinking and dialogue
- The relative roles of public and private universities
- The relative roles of U.S. and non-U.S. universities
- The relative approaches of universities and the military in fostering diversity
- Security and classification requirements.

The Technology Tsunami and the National Security Establishment

Dr. Richard Danzig discussed how the U.S. national security establishment can address the challenge of absorbing new technologies. Although he considers the national security community's approach to developing new technologies admirably innovative, the community also tends to be sheltered and impermeable to outside influences. In considering the future of technology development, he highlighted three aspects:

- *Loss of ownership*. Historically, DoD was able to identify technology needs, conduct the required research, and purchase systems that fielded the developed technologies, In the future, DoD is increasingly likely to be responding and adapting to commercially developed technologies (although there will remain some areas, such as nuclear weapons or submarines, where DoD will remain the technology originator). In addition, the United States is likely to face a future where other countries' technological strengths match or exceed our own, and where multinational companies' interests may not align with the national interest. The combination of trends suggests an increasing reliance on adapting commercial off-the-shelf technologies, open-source intelligence gathering, and more rapid and flexible procurement approaches.
- *Mismatches in pace*. Moore's Law may apply to computers, but not to the pace of bureaucratic decision-making or to refreshing human talent. This poses a special problem for DoD because of its reliance on long-lived weapons systems optimized for particular conditions, which may be disrupted by rapidly changing mission demands. DoD also needs to be prepared for strategic technology surprise and focus on remaining ahead where technologies create first-mover advantages. Bureaucratic pace does not accelerate either.
- *Compounding complexity*. Dr. Danzig pointed out that it is not clear that we understand the details or consequences of the technologies we've created. Complexity is compounding with time; as new and legacy systems commingle, systems integrate with each other. Additional complexity-related problems specific to DoD are that cyber-physical connections are a challenge and the complexity may create wholly new dimensions of warfare and uncertainties in the value of existing warfighting concepts. He recommended two approaches DoD might take to combatting complexity:
  - First, resilience and flexibility should compete with efficiency and effectiveness as investment priorities – systems should be designed for multiple potential use cases rather than optimized for a single scenario.
  - Second, investment in artificial intelligence may be a mechanism for staying abreast of the growing complexity the natural security community faces.

Dr. Danzig raised the concern that bureaucracies are likely to respond to these challenges by making incremental changes rather than fundamentally shifting incentives. One concern lies in human resources and manpower. As an example, he pointed to trying to infuse technological capabilities throughout the national security community rather than creating specific authorities and job classifications aimed at recruiting and retaining technically savvy personnel – which has the effect of sequestering them and denying them opportunities for promotion and command. Similarly, he raised the concern that bureaucracies tend to create special-purpose management structures (e.g., Special Projects Offices) rather than by using bureaucratic competition to change the incentives of existing organizations.

Points raised in the question and answer session included:

- How restructuring organizations can spur innovation to address challenges
- The role of the new White House Commission on Enhancing National Cybersecurity
- Comparison of cybersecurity challenges to those of a physical frontier
- How to prioritize future R&D investments in an uncertain world
- Under what circumstances the U.S. should prioritize resilience as compared with developing and retaining first-mover advantages.

DSSG Program Agenda

Wednesday, March 30, 2016

6:00 AM	**Registration begins**	
7:30 AM	**Breakfast**	
8:30 AM	**Welcome**	Dr. David S.C. Chu
8:45 AM	**Opening Remarks**	Dr. Robert E. Roberts
9:00 AM	**S&T Perspectives in National Security**	Moderator: Dr. Craig Fields Participants: Ms. Jill Hruby, Mr. Tom Kalil, Ms. Heidi Shyu
10:30 AM	**Breakthrough Technologies for National Security**	Dr. Arati Prabhakar
11:00 AM	**Break**	
11:30 AM	**Role of Academia in National Security**	Moderator: Dr. Steve Koonin Participants: Dr. Werner Dahm, Dr. Brett Giroir, Dr. Ann Karagozian
12:30 PM	**Lunch w/speaker**	The Honorable Frank Kendall
1:30 PM	**Break**	
2:30 PM	**Climate/Energy Security**	The Honorable Franklin (Lynn) Orr
3:30 PM	**Break**	
4:00 PM	**Homeland Security Challenges**	Governor Tom Ridge
5:00 PM	**Break**	
6:30 PM	**Reception**	

Thursday, March 31, 2016

7:30 AM	**Breakfast**	
8:30 AM	**Using Technology to Create Strategic Advantage: Past Perspectives and Future Directions**	Moderator: Dr. David S.C. Chu Participants: Dr. Paul G. Kaminski, The Honorable Stephen Welby, General Larry D. Welch, USAF (Ret.)
9:30 AM	**Break**	
10:00 AM	**The Role of Academics in National Issues**	Dr. Thomas F. Rosenbaum
11:00 AM	**National Security Challenges**	Dr. Richard Danzig
12:00 PM	**Closing Remarks**	Dr. David S.C. Chu

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Biographies of Symposium Presenters

David S.C. Chu

David Chu serves as President of the Institute for Defense Analyses. IDA is a non-profit corporation operating in the public interest. Its three federally funded research and development centers provide objective analyses of national security issues and related national challenges, particularly those requiring extraordinary scientific and technical expertise.
As president, Dr. Chu directs the activities of more than 1,000 scientists and technologists. Together, they conduct and support research requested by federal agencies involved in advancing national security and advising on science and technology issues.

Dr. Chu served in the Department of Defense as Under Secretary of Defense for Personnel and Readiness from 2001-2009, and earlier as Assistant Secretary of Defense and Director for Program Analysis and Evaluation from 1981-1993.

From 1978-1981 he was the Assistant Director of the Congressional Budget Office for National Security and International Affairs.

Dr. Chu served in the U. S. Army from 1968-1970. He was an economist with the RAND Corporation from 1970-1978, director of RAND's Washington Office from 1994-1998, and vice president for its Army Research Division from 1998-2001.

He earned a bachelor of arts in economics and mathematics, and his doctorate in economics, from Yale University.

Dr. Chu is a member of the Defense Science Board and a Fellow of the National Academy of Public Administration. He is a recipient of the Department of Defense Medal for Distinguished Public Service with Gold Palm, the Department of Veterans Affairs Meritorious Service Award, the Department of the Army Distinguished Civilian Service Award, the Department of the Navy Distinguished Public Service Award, and the National Academy of Public Administration's National Public Service Award.

Werner J.A. Dahm

Founding Director and Chief Scientist, Security and Defense Systems Initiative
ASU Foundation Professor of Aerospace and Mechanical Engineering
Arizona State University
Tempe, AZ 85287-5604, USA

Ph.D. Aeronautics California Institute of Technology 1985
M.S. Mechanical Engineering University of Tennessee Space Institute 1981
B.S.E. Mechanical Engineering University of Alabama in Huntsville 1978

- Founding Director and Chief Scientist, Security and Defense Systems Initiative (SDSI) – Arizona State University
- ASU Foundation Professor of Aerospace and Mechanical Engineering – Arizona State University
- Chair, U.S. Air Force Scientific Advisory Board (SAB) – Air Force Pentagon, Washington, D.C.
- Former Chief Scientist of the U.S. Air Force (AF/ST) – Headquarters Air Force, Pentagon, Washington, D.C.

- Air Force Decoration for Exceptional Civilian Service – United States Air Force
- Emeritus Professor of Aerospace Engineering – The University of Michigan
- Fellow – American Institute of Aeronautics & Astronautics (AIAA)
- Fellow – American Physical Society (APS), Division of Fluid Dynamics
- Former Consultant, Defense Science Board (DSB) – Defense Pentagon, Washington, D.C.
- Air Force Meritorious Civilian Service Award – United States Air Force
- George J. Huebner Research Excellence Award – The University of Michigan
- 1938E Distinguished Achievement Award – The University of Michigan
- William F. Ballhaus Aeronautics Prize – Caltech
- Donald Wills Douglas Prize Fellowship – Caltech

Professor Werner J.A. Dahm is ASU Foundation Professor of Aerospace and Mechanical Engineering, and Founding Director and Chief Scientist, Security & Defense Systems Initiative at Arizona State University (ASU).

He previously was the Chief Scientist of the U.S. Air Force (AF/ST), a member of Headquarters Air Force in the Pentagon serving as the direct science and technology advisor to the Secretary of the Air Force and the Air Force Chief of Staff. As the Air Force's Chief Scientist he led development of "Technology Horizons", the Headquarterslevel vision identifying key science and technology focus areas for the U.S. Air Force during 2010-2030.

He is the current Chair of the U.S. Air Force Scientific Advisory Board (SAB), has served with the SAB since 2006 and has served on numerous task forces of the Defense Science Board (DSB) for the Office of the Under Secretary of Defense (OUSD AT&L), and is a past member of the Defense Science Study Group (DSSG) at the Institute for Defense Analyses (IDA) in Washington, D.C. He is a Fellow of the American Physical Society (APS) in the Division of Fluid Dynamics (DFD), a Fellow of the American Institute of Aeronautics and Astronautics (AIAA), a recipient of the William F. Ballhaus Aeronautics Prize from Caltech, the 1938E Distinguished Achievement Award from the University of Michigan, and the George J. Huebner Research Excellence Award from The University of Michigan.

He received his Ph.D. degree in Aeronautics from Caltech in 1985, and previously worked as a Research Engineer in the Propulsion Wind Tunnel Facility at the USAF Arnold Engineering Development Center (AEDC) in Tullahoma, TN. He also has an M.S. degree in Mechanical Engineering from The University of Tennessee Space Institute (UTSI) in Tullahoma, TN and a B.S.E. in Mechanical Engineering from The University of Alabama in Huntsville.

Dr. Dahm also is Emeritus Professor of Aerospace Engineering at The University of Michigan, where he was on the faculty for 25 years and led the Laboratory for Turbulence & Combustion. He is an author of over 200 refereed technical articles, conference papers, and technical publications, a holder of six U.S. and international patents, and has given over 270 technical presentations, including more than 180 invited, plenary, and keynote lectures worldwide, on topics dealing with aerospace engineering and defense science. Additionally, he has founded and served on the Board of two technology-oriented entrepreneurial companies, and has served extensively on technical advisory and organizational committees for numerous technical conferences, and as a consultant for industry.

Richard Danzig

Richard Danzig is a Senior Advisor to the Johns Hopkins Applied Physics Laboratory, a consultant to the Intelligence Advanced Research Projects Activity (IARPA), Chair of the Advisory Panel for Idaho National Laboratories' Innovation Center, and a member of the Toyota Research Institute Advisory Board. He is also a member of the Defense Policy Board, The President's Intelligence Advisory Board, and the Homeland Security Secretary's Advisory Council, a Trustee of Reed College and of the RAND Corporation, a Director of the Center for a New American Security and a Director of Saffron Hill Ventures (a European investment firm).

In recent time he has been a director of National Semiconductor Corporation (NY Stock Exchange) and Human Genome Sciences Corporation (NASDAQ). He has also served as The Chairman of the Board of The Center for a New American Security, Vice Chair of RAND, and Chairman of the Board of the Center for Strategic and Budgetary Assessments.

Dr. Danzig served as the 71st Secretary of the Navy from November 1998 to January 2001. He was the Under Secretary of the Navy between 1993 and 1997. From the spring of 2007 through the Presidential election of 2008, Dr. Danzig was a senior advisor to Senator Obama on national security issues.

Dr. Danzig is a member of the Aspen Strategy Group and a senior advisor at the Center for New American Security, the Center for Naval Analyses, and the Center for Strategic and International Studies in Washington DC. He has served in recent years as a consultant to the Departments of Defense and Homeland Security on national security issues.

Dr. Danzig was born in New York City in 1944. He received a B.A. degree from Reed College, a J.D. degree from Yale Law School, and Bachelor of Philosophy and Doctor of Philosophy degrees from Oxford University, where he was a Rhodes Scholar. Upon his graduation from Yale, Dr. Danzig served as a law clerk to U.S. Supreme Court Justice Byron White.

Craig I. Fields

Dr. Craig I. Fields received his BS degree from the Massachusetts Institute of Technology and his Ph.D. from the Rockefeller University. He served on the faculty of Harvard University; he was the Director of the Defense Advanced Research Projects Agency (DARPA); he was the Chairman and Chief Executive Officer of the Microelectronics and Computer Technology Corporation (MCC). He is Chairman of the Defense Science Board, an advisory board for the Secretary of Defense.

In 1988, Dr. Fields was awarded the President's Distinguished Executive Rank Award for outstanding service, and in 1990 the President's Meritorious Executive Rank Award. In 2001 Dr. Fields was awarded the Department of Defense Medal for Distinguished Public Service. In 2005 Dr. Fields was awarded the Department of Defense Eugene G. Fubini Award for contributions to national security. Dr. Fields was elected a fellow of the American Association for the Advancement of Science. In 1992, Dr. Fields received the IEEE Award for Distinguished Contributions to Public Service. Dr. Fields is a Member of the Council on Foreign Relations. Formerly, Dr. Fields was a Member of the Council on Competitiveness, and was a Principal of the Council for Excellence in Government.

Brett P. Giroir

Dr. Giroir is an internationally recognized expert in life science innovation and the founding CEO of Health Science and Biosecurity Partners, LLC. His clients include major academic institutions, federal agencies, global corporations, and biotechnology start-ups. He currently serves as Senior Fellow at the Texas Medical Center Health Policy Institute, Strategic Advisor for the TMCX Innovation Institute, Member of the Texas Task Force for Infectious Disease Preparedness and Response, Special Advisor to the President of UNT Health Science Center, and Adjunct Professor of Pediatrics and Tropical Medicine at the Baylor College of Medicine. Dr. Giroir previously served as Chief Executive Officer of the Texas A&M Health Science Center, Professor in Medicine and Engineering, and Vice Chancellor for Research for the Texas A&M University System. He was the founder and Principal Investigator of the Department of Health and Human Services Center for Innovation in Advanced Development and Manufacturing at Texas A&M – a novel public-private partnership designed to enhance the nation's biosecurity preparedness, with a contract value approaching $3 billion. Dr. Giroir's background includes national service as the Director of the Defense Advanced Research Projects Agency (DARPA) Defense Sciences Office, where he led ground breaking research initiatives in the fields of physics, materials science, engineering, mathematics, and biology. Prior to joining DARPA, Dr. Giroir was Professor, Endowed Chair, and Associate Dean at the University of Texas Southwestern Medical Center and the inaugural chief medical officer at Children's Health, Dallas, where he practiced pediatric critical care medicine.

Dr. Giroir serves on the Scientific Advisory Boards of the Biodesign Institute at Arizona State University, the A. Alfred Taubman Medical Research Institute at the University of Michigan, and as a volunteer advisor for numerous "start-ups." He received his undergraduate degree magna cum laude from Harvard University, his M.D., AOA, from the University of Texas Southwestern Medical Center, and post-doctoral training in the laboratory of Dr. Bruce Beutler at the Howard Hughes Medical Institute.

Dr. Giroir's notable awards include the U.S. Secretary of Defense Medal for Outstanding Public Service and the Texas A&M University System Award for Innovation. He was also named by the Dallas Morning News as a finalist for Texan of the Year, and most recently served as Chair of the Congressional Choice Act Blue Ribbon Panel to review and recommend reforms for the Veterans Health System.

Jill M. Hruby

Jill Hruby is the director of Sandia National Laboratories and president of Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, which operates Sandia for the U.S. Department of Energy's National Nuclear Security Administration (NNSA). Sandia has principal sites in Albuquerque, New Mexico, and Livermore, California, operating revenue of about $2.6 billion, and more than 10,000 employees.

In 2010, Hruby came to Sandia's New Mexico site after 27 years at Sandia's California location to become vice president of the Energy, Nonproliferation, and High-Consequence Security Division, and leader of Sandia's International, Homeland, and Nuclear Security Program Management Unit.

As vice president, Hruby oversaw more than 1,300 employees and contractors and managed work in such areas as global security, energy technologies, weapon and force protection, critical asset protection, the nuclear fuel cycle, geoscience, and climate. The PMU mission encompassed nonproliferation and arms control; securing and safeguarding nuclear weapons and nuclear materials; protecting critical U.S. government assets and installations; ensuring the resilience of physical and cyber infrastructures; and reducing the risks of terrorist threats and catastrophic events.

Hruby joined Sandia in 1983 and did research in thermal and fluid sciences, solar energy, and nuclear weapon components. During her career, she has been engaged in nanoscience research, hydrogen storage, mechanical component design, thermal analysis and microfluidics.

She earned her first management appointment in 1989 and held technical leadership positions at the California lab in polymer and electrochemical technologies, materials synthesis, and inorganic and physical chemistry for eight years. She then served as senior manager in organizations responsible for weapon components, micro-technologies, and materials processing.

Hruby was named a technical director in 2003, first leading the Materials and Engineering Sciences Center and its work in hydrogen science and engineering and microsystem science and fabrication. In 2005 Jill became director of the Homeland Security and Defense Systems Center, fostering Sandia work in systems analysis, applied research, and systems engineering, primarily for homeland security and nuclear weapons missions.

Hruby earned her bachelor's degree from Purdue University and her master's degree from the University of California at Berkeley, both in mechanical engineering. She has authored numerous publications, holds three patents in microfabrication and won an R&D 100 Award in solid-state radiation detection. She serves on the Threat Reduction Advisory Committee for the Department of Defense, and the Board of Chemical Science and Technology for the National Academy of Sciences. She has served on several university advisory boards, on community boards in Livermore and Albuquerque and as the campus executive at Georgia Institute of Technology.

Paul G. Kaminski

Paul G. Kaminski is Chairman and CEO of Technovation, Inc., a small consulting company dedicated to fostering innovation, and to the development of business and investment strategies related to the application of advanced technology in the aerospace and defense sectors.

Dr. Kaminski served as the Under Secretary of Defense for Acquisition and Technology from October 3, 1994 to May 16, 1997. He was responsible for all Department of Defense (DoD) research, development, and acquisition programs. He also had responsibility for DoD logistics, environmental security, international programs, the defense industrial base, and military construction. The annual budget for these entities exceeded $100 billion.

Dr. Kaminski has had a continuing career involving large program management, and the development and application of advanced technology in both the private and public sectors. He served as Chairman and Chief Executive Officer of Technology Strategies and Alliances, a technology – oriented investment banking and consulting firm. He has served as a consultant and advisor to a wide variety of government agencies and as chairman, director or trustee of several defense and technology oriented companies.

His previous government experience includes a 20-year career as an officer in the U.S. Air Force. During 1981-1984, he served as Director for Low Observables Technology, with responsibility for overseeing the development, production and fielding of major "stealth" systems (e.g., F-117, B-2). He also led the initial development of a National Reconnaissance Office space system and related sensor technology. Early in his career, he was responsible for test and evaluation of inertial guidance components for the Minuteman missile and terminal guidance systems for our first precision guided munitions.

Dr. Kaminski has served on the President's Intelligence Advisory Board, the FBI Director's Advisory Board, the Director of National Intelligence Senior Advisory Group, the Senate Select Committee on Intelligence Technical Advisory Board, and the National Academies Air Force Studies Board. He currently serves on the Defense Science Board (which he has chaired twice). He is a member of the National Academy of Engineering, a Fellow of the Institute for Electrical and Electronics Engineers, and a Fellow and an Honorary Fellow of the American Institute of Aeronautics & Astronautics. He has chaired the board of the RAND Corporation, served as a Director of General Dynamics, and currently chairs the boards of Exostar, HRL (formerly the Hughes Research Labs), and Seagate Government Solutions. He is a Director of RAND, Bay Microsystems, CoVant Technologies, LGS Innovations, the Johns Hopkins Applied Physics Lab, and the USAF Academy Endowment. He serves as an advisor to the MIT Lincoln Laboratory, and has authored publications dealing with inertial and terminal guidance system performance, simulation techniques, Kalman filtering and numerical techniques applied to estimation problems.

Dr. Kaminski has received the following awards: The National Medal of Technology, Department of Defense Medal for Distinguished Public Service (5 awards), Defense Distinguished Service Medal, Director of Central Intelligence Director's Award, Defense Intelligence Agency Director's Award, Legion of Merit with Oak Leaf Cluster, Air Force Academy 2002 Distinguished Graduate Award, the Ronald Reagan Award for Missile Defense, the Reed award for Aeronautics, The IEEE Ramo award for Systems Engineering, the International Strategic Studies Association Possony Medal for Outstanding Contributions to Strategic Progress through Science and Technology, the Marine Scholarship Leatherneck Award, the AOC Gold Medal, the Netherlands Medal of Merit in Gold, the French Republic Legion d'Honneur, the SPIE Lifetime Achievement award, and the Air Force Systems Command Scientific Achievement Award. He has been recognized as a Pioneer of National Reconnaissance and a Pioneer of Stealth.

Dr. Kaminski was born in Cleveland, Ohio. He received a Bachelor of Science from the Air Force Academy, Master of Science degrees in both Aeronautics and Astronautics and in Electrical Engineering from the Massachusetts Institute of Technology, and a Ph.D. in Aeronautics and Astronautics from Stanford University. He and his wife, Julie, have two children, and six grandchildren.

Tom Kalil

Tom Kalil is the Deputy Director for Technology and Innovation for the White House Office of Science and Technology Policy and Senior Advisor for Science, Technology and Innovation for the National Economic Council. In this role, Tom serves as a senior White House staffer charged with

coordinating the government's technology and innovation agenda. Prior to serving in the Obama Administration, Tom was Special Assistant to the Chancellor for Science and Technology at the University of California, Berkeley. In 2007 and 2008, Tom was Chair of the Global Health Working Group for the Clinton Global Initiative. Previously, Tom served for 8 years in the Clinton White House, ultimately as the Deputy Assistant to the President for Technology and Economic Policy, and the Deputy Director of the National Economic Council. Tom received a B.A. from the University of Wisconsin at Madison, and completed graduate work at Tufts University's Fletcher School.

Ann R. Karagozian

Ann Karagozian is the Interim Vice Chancellor for Research at the University of California, Los Angeles, overseeing a research enterprise that averages over a billion dollars a year in extramural funding. Since 1982, Karagozian has been a Professor in the Department of Mechanical and Aerospace Engineering at UCLA. Her research interests lie in fluid mechanics and combustion as applied to improved energy efficiency, reduced emissions, and advanced air breathing and rocket propulsion systems. Professor Karagozian is a Past Chair and is the current Councilor of the American Physical Society/Division of Fluid Dynamics. She was a member of the Air Force Scientific Advisory Board for a dozen years, twice receiving the Air Force Decoration for Exceptional Civilian Service, serving as Vice Chair (2005-2009), and chairing numerous technical studies, including a 2006 study on Air Vehicle Fuel Efficiency and a 2010 study on Future Launch Vehicles. Prof. Karagozian is a Fellow of the APS, AIAA, and ASME. She received her B.S. in Engineering from UCLA and her M.S. and Ph.D. in Mechanical Engineering from the California Institute of Technology. She is currently a member of the Board of Trustees of the Institute for Defense Analyses, and is an alumna of the Defense Science Study Group (1994-5) as well as a current DSSG mentor.

Frank Kendall

Senate Confirmed in May 2012, Mr. Frank Kendall currently serves as the Under Secretary of Defense for Acquisition, Technology and Logistics (AT&L). In this capacity, he is responsible to the Secretary of Defense for all matters pertaining to acquisition; research and engineering; developmental testing; contract administration; logistics and materiel readiness; installations and environment; operational energy; chemical, biological, and nuclear weapons; the acquisition workforce; and the defense industrial base. He is the leader of the Department of Defense's efforts to increase the Department's buying power and improve the performance of the defense acquisition enterprise. Prior to this appointment, from March 2010 – May 2012 he served as the Principal Deputy Under Secretary and also as the Acting Under Secretary.

Mr. Kendall has over 40 years of experience in engineering, management, defense acquisition, and national security affairs in private industry, government, and the military. He has been a consultant to defense industry firms, non-profit research organizations, and the Department of Defense in the areas of strategic planning, engineering management, and technology assessment. Mr. Kendall was Vice President of Engineering for Raytheon Company, where he was responsible for management direction to the engineering functions throughout the company and for internal research and development. Before joining the Administration, Mr. Kendall was a Managing Partner at Renaissance Strategic Advisors, a Virginia-based aerospace and defense sector consulting firm.

Within government, Mr. Kendall held the position of Director of Tactical Warfare Programs in the Office of the Secretary of Defense and the position of Assistant Deputy Under Secretary of Defense for Strategic Defense Systems. Mr. Kendall is a former member of the Army Science Board and the Defense Intelligence Agency Science and Technology Advisory Board and he has been a consultant to the Defense Science Board and a Senior Advisor to the Center for Strategic and International Studies. Mr. Kendall also spent ten years on active duty with the Army serving in Germany, teaching Engineering at West Point, and holding research and development positions.

Mr. Kendall is an attorney and has been active in the field of human rights, working primarily on a pro bono basis. He has worked with Amnesty International USA, where he served as a member of the Board of Directors, with Human Rights First, for which he was an observer at Guantanamo, and with the Tahirih Justice Center, where he was Chair of the Board of Directors.

Over the course of his career as a public servant, Mr. Kendall was awarded the following federal civilian awards: Defense Distinguished Public Service Award, Defense Distinguished Civilian Service Medal, Secretary of Defense Meritorious Civilian Service Medal, Presidential Rank Award of Distinguished Executive (Senior Executive Service), Presidential Rank Award of Meritorious Executive (Senior Executive Service), and Army Commander's Award for Civilian Service. He also holds the following military awards (US Army): Meritorious Service Medal with oak leaf cluster, Army Commendation Medal, and National Defense Service Medal. Mr. Kendall is a Distinguished Graduate of the U.S. Military Academy at West Point, an Army War College Graduate, and he holds a Masters Degree in Aerospace Engineering from California Institute of Technology, a Master of Business Administration degree from the C.W. Post Center of Long Island University, and a Juris Doctor degree from Georgetown University Law Center.

Steven E. Koonin

Steven E. Koonin was appointed as the founding Director of NYU's Center for Urban Science and Progress in April 2012. That consortium of academic, corporate, and government partners will pursue research and education activities to develop and demonstrate informatics technologies for urban problems in the "living laboratory" of New York City.

He previously served as the U.S. Department of Energy's second Senate-confirmed Under Secretary for Science from May 19, 2009 through November 18, 2011. As Under Secretary for Science, Dr. Koonin functioned as the Department's chief scientific officer, coordinating and overseeing research across the DOE. He led the preparation of the Department's 2011 Strategic Plan and was the principal author of its Quadrennial Technology Review. Dr. Koonin particularly championed research programs in High Performance Simulation, Exascale Computing, Inertial Fusion Energy, and Greenhouse Gas Monitoring, Reporting, and Verification. He also provided technical counsel on diverse nuclear security matters.

He joined the California Institute of Technology's faculty in 1975, was a research fellow at the Niels Bohr Institute during 1976-1977, and was an Alfred P. Sloan Foundation Fellow during 1977-1979. He became a professor of theoretical physics at Caltech in 1981 and served as Chairman of the Faculty from 1989-1991. Dr. Koonin was the seventh provost of Caltech from 1995-2004. In that capacity, he was involved in identifying and recruiting 1/3 of the Institute's

professorial faculty and left an enduring legacy of academic and research initiatives in the biological, physical, earth, and social sciences, as well as the planning and development of the Thirty-Meter Telescope project.

As the Chief Scientist at BP from 2004 to early 2009, Dr. Koonin developed the long-range technology strategy for alternative and renewable energy sources. He managed the firm's university–based research programs and played a central role in establishing the Energy Biosciences Institute at the University of California Berkeley, the Lawrence Berkeley National Laboratory, and the University of Illinois at Urbana-Champaign.

Dr. Koonin is a member and past chair of the JASON Study Group, advising the U.S. Government on technical matters of national security. He has served on numerous advisory committees for the Department of Energy, the National Science Foundation, and the Department of Defense, including the Defense Science Board and the CNO's Executive Panel. He is a member of the Council on Foreign Relations and a fellow of the American Physical Society, the American Association for the Advancement of Science, and the American Academy of Arts and Sciences, the Trilateral Commission and the U.S. National Academy of Sciences . In 1985, Dr. Koonin received the Humboldt Senior U.S. Scientist Award and, in 1998 the Department of Energy's E.O. Lawrence Award for his "broad impact on nuclear many-body physics, on astrophysics, and on a variety of related fields where sophisticated numerical methods are essential; and in particular, for his breakthrough in nuclear shell model calculations centered on an ingenious method for dealing with the huge matrices of heavy nuclei by using path integral methods combined with the Monte Carlo technique."

Franklin (Lynn) Orr

Dr. Franklin (Lynn) M. Orr was sworn in as the Under Secretary for Science and Energy on December 17, 2014.

As the Under Secretary, Dr. Orr is the principal advisor to the Secretary and Deputy Secretary on clean energy technologies and science and energy research initiatives. Dr. Orr is the inaugural Under Secretary for the office, which was created by Secretary of Energy Ernest Moniz to closely integrate DOE's basic science, applied research, technology development, and deployment efforts. As Under Secretary, he oversees DOE's offices of Electricity Delivery and Energy Reliability, Energy Efficiency and Renewable Energy, Fossil Energy, Indian Energy Policy and Programs, Nuclear Energy, and Science. In total, these programs steward the majority of DOE's National Laboratories.

Prior to joining the Department of Energy, Dr. Orr was the Keleen and Carlton Beal Professor Emeritus in the Department of Energy Resources Engineering at Stanford University. He joined Stanford in 1985. He served as the founding director of the Precourt Institute for Energy at Stanford University from 2009 to 2013. He was the founding director of the Stanford Global Climate and Energy Project from 2002 to 2008, and he served as Dean of the School of Earth Sciences at Stanford from 1994 to 2002. He was head of the miscible flooding section at the New Mexico Petroleum Recovery Research Center, New Mexico Institute of Mining and Technology from 1978 to 1985, a research engineer at the Shell Development Company Bellaire Research

Center from 1976 to 1978, and assistant to the director, Office of Federal Activities, U.S. Environmental Protection Agency from 1970 to 1972. He holds a Ph.D. from the University of Minnesota and a B.S. from Stanford University, both in Chemical Engineering.

Dr. Orr is also a member of the National Academy of Engineering. He served as a member of the Board of Directors of the Monterey Bay Aquarium Research Institute from 1987 to 2014, and was a member of the Board of Trustees of the David and Lucile Packard Foundation from 1999 to 2008, for which he has also chaired the Science Advisory Panel for the Packard Fellowships in Science and Engineering from 1988 to 2014. He served as a member of the 2008/09 National Research Council Committee on America's Energy Future.

Tom Ridge

Tom Ridge is Chairman of Ridge Global. He provides clients with solutions to cyber security, international security and risk management issues.

Following the tragic events of September 11th, 2001, Tom Ridge became the first Assistant to the President for Homeland Security and, on January 24, 2003, became the first Secretary of the U.S. Department of Homeland Security. The creation of the country's 15th Cabinet Department marked the largest reorganization of government since the Truman administration and another call to service for the former soldier, congressman and governor of Pennsylvania.

During his DHS tenure, Secretary Ridge worked with more than 180,000 employees from a combined 22 agencies to create an agency that facilitated the flow of people and goods, instituted layered security at air, land and seaports, developed a unified national response and recovery plan, protected critical infrastructure, integrated new technology and improved information sharing worldwide. Tom Ridge served as Secretary of this historic and critical endeavor until February 1, 2005.

Before the events of September 11th, Tom Ridge was twice elected Governor of Pennsylvania. He served as the state's 43rd governor from 1995 to 2001. Governor Ridge's aggressive technology strategy helped fuel the state's advances in economic development, education, health care and the environment.

He serves on the boards of the Institute for Defense Analyses, the Center for the Study of the Presidency and Congress and other private and public entities. He is currently chairman of the U.S. Chamber of Commerce's National Security Task Force.

He graduated from Harvard with honors. After his first year at Penn State University's Dickinson School of Law, he was drafted into the U.S. Army, where he served as an infantry staff sergeant in Vietnam, earning the Bronze Star for Valor, the Combat Infantry Badge and the Vietnamese Cross of Gallantry.

After returning to Pennsylvania and to Dickinson, he earned his law degree and, later, became one of the first Vietnam combat veterans elected to the U.S. House of Representatives, where he served six terms.

Robert E. Roberts

Dr. Robert Roberts is IDA's Senior Scientist at the Institute for Defense Analyses and former Director of the Science and Technology Policy Institute. He is also the former Vice President for Research and Director of IDA's Science and Technology Division. Before joining the Institute, he spent several years with the Department of Energy, and, prior to that, he was associate professor of chemistry at Indiana University and a research staff member in IDA's Science and Technology Division. Dr. Roberts is founder, former director and mentor for the IDA Defense Science Study Group, a program established to foster interest in national security issues among outstanding young professors of science and engineering.

Dr. Roberts has served on several university, government and non-profit advisory boards including the National Academies Board of Chemical Sciences and Technology. Roberts received his Bachelor's Degree in chemistry from the Carnegie Institute of Technology (now Carnegie Mellon), his Ph.D. in physical chemistry from the University of Wisconsin, and was a National Science Foundation postdoctoral research fellow at MIT.

Thomas F. Rosenbaum

Thomas F. Rosenbaum is the ninth president of the California Institute of Technology and Professor of Physics. He is an expert on the quantum mechanical nature of materials, conducting research at Bell Laboratories, IBM Watson Research Center, and the University of Chicago, where he served as Vice President for Research and for Argonne National Laboratory and then provost, before moving to Caltech in 2014. He received his bachelor's degree in physics with honors from Harvard University and a Ph.D. in physics from Princeton University. Rosenbaum is an elected fellow of the American Physical Society, the American Association for the Advancement of Science, and the American Academy of Arts and Sciences.

Heidi Shyu

The Honorable Heidi Shyu, was the Assistant Secretary of the Army for Acquisition, Logistics and Technology, ASA(ALT), from September 21, 2012 to Jan. 31, 2016. Prior to this, she served as the Acting ASA(ALT), from June 4, 2011 and the Principal Deputy starting November 8, 2010.

As the ASA(ALT), she served as the Army Acquisition Executive, the Senior Procurement Executive, the Science Advisor to the Secretary of the Army, and the Army's Senior Research and Development official. She had principal responsibility for all Department of the Army matters related to logistics.

She led the execution of the Army's acquisition function and the acquisition management system. Her responsibilities included providing oversight for the life cycle management and sustainment of Army weapons systems and equipment from research and development through test and evaluation, acquisition, logistics, fielding, and disposition. HON. Shyu also oversaw the Elimination of Chemical Weapons Program. In addition, she was responsible for appointing, managing, and evaluating Program Executive Officers and managing the Army Acquisition Corps and the Army Acquisition Workforce.

Prior to this position, she was the Vice President of Technology Strategy for Raytheon Company's Space and Airborne Systems. She also held several senior leadership positions there, including Corporate Vice President of Technology and Research, Vice President and Technical Director of Space and Airborne Systems, Vice President of Unmanned and Reconnaissance Systems, Senior Director of Unmanned Combat Vehicles, Senior Director of Joint Strike Fighter (JSF), and Director of JSF Integrated Radar/Electronic Warfare Sensors. As Director of JSF Antenna Technologies at Raytheon, she was responsible for the development of lightweight, low-cost, Tile Active Electronically Scanned Antenna technologies. She also served as the Laboratory Manager for Electromagnetic Systems.

In addition to her extensive experience at Raytheon, she served as a Project Manager at Litton Industries and was the Principal Engineer for the Joint STARS Self Defense Study at Grumman. She began her career at the Hughes Aircraft Company.

Honorable Shyu holds a Bachelor of Science Degree in Mathematics from the University of New Brunswick in Canada, a Master of Science Degree in Mathematics from the University of Toronto, Master of Science Degree in System Science (Electrical Engineering) from the University of California, Los Angeles (UCLA), and the Engineer Degree from UCLA. She is also a graduate of the UCLA Executive Management Course and the University of Chicago Business Leadership Program.

A member of the Air Force Scientific Advisory Board from 2000 to 2010, HON. Shyu served as the Vice Chairman from 2003 to 2005 and as Chairman from 2005 to 2008.

HON. Shyu is the recipient of the DoD Medal for Distinguished Public Service, Dept. of the Army Medal for Distinguished Civilian Service, Department of the Air Force Decoration for Exceptional Civilian Service, General Brehon B. Somerville Medal of Excellence, the Knowlton Award from Military Intelligence Corp., National Infantry Association Order of Saint Maurice, Army Aviation Association's The Knight of the Honorable Order of Saint Michael, University of California, Los Angeles Engineering Alumni Professional Achievement Award, Raytheon Hero Award, N. Myles Brown Science Award.

Stephen P. Welby

Mr. Stephen P. Welby was confirmed as the Assistant Secretary of Defense for Research and Engineering (ASD(R&E)) on December 14, 2015, and serves as the Chief Technology Officer for the Department of Defense and the principal advisor to the Secretary on all matters relating to science, technology, research and engineering. As ASD(R&E), Mr. Welby is responsible for the Department's strategies and supporting plans to develop and leverage the technologies needed to ensure continued U.S. technological superiority. He provides leadership to, and establishes policy and guidance for, the development and execution of the DoD Research and Engineering program. He oversees matters from basic science and capability prototyping to research and engineering at the Department's laboratories, promotes coordination and cooperation across the DoD and between the DoD and other federal and non-federal agencies and organizations, and ensures technical exchange with allied and friendly nations.

Mr. Welby had previously served as Deputy Assistant Secretary of Defense for Systems Engineering, and was responsible for establishing and executing engineering policy and oversight across the Department. His responsibilities included engineering design, development and manufacturing of

complex military systems, and the engineering review, analysis and technical risk assessment of the Department's portfolio of major acquisition programs. He provided functional leadership to more than 40,000 technical professionals in the DoD Engineering and Production, and Quality and Manufacturing workforce. Mr. Welby also served as the Defense Standardization Executive, directing the DoD program to develop and maintain defense-critical government and commercial technical standards.

Mr. Welby has more than 28 years of government and industrial experience in technology and product development, including senior leadership positions at the Defense Advanced Research Projects Agency (DARPA). His experience includes development of leading-edge aeronautical and space systems, robotics, advanced weapons, high-performance software, and military sensor systems.

Mr. Welby holds a bachelor of science degree in chemical engineering from The Cooper Union for the Advancement of Science and Art, a master's degree in business administration from the Texas A&M University, and master's degrees in computer science and applied mathematics from The Johns Hopkins University.

Larry D. Welch

General Welch is a senior fellow at IDA. He served for 16 years as President and CEO of IDA following his retirement from the U.S. Air Force in 1990. He is a former Chief of Staff, U.S. Air Force.

During his 38 years in the Air Force, General Welch served in operational and staff assignments in training organizations and tactical fighter units worldwide to include combat in Vietnam. He was the Commander of the Tactical Air Command, Air Force Central command and 9th Air Force; Deputy Chief of Staff, Programs & Resources, Headquarters, USAF; Vice Chief of Staff, USAF; and Commander of the Strategic Air Command prior to becoming Chief of Staff, USAF. As Chief of Staff, he was responsible for organizing, equipping and executive direction of the U.S. Air Force. He was a member of the Joint Chiefs of Staff and served as military advisor to the Secretary of Defense and the President of the U.S. on national security matters.

He received a Bachelor of Science in Business Administration from the University of Maryland, a MS in International Relations from George Washington University and is a graduate of the Armed Forces Staff College, National War College. He also is a graduate of the Harvard National Security Seminar.

General Welch is a Director of the Aerospace Education Foundation, the Air Force Academy Foundation, the Henry L. Stimson Center, and the Sandia National Laboratories. He is Chairman of the Permanent Task Force on Nuclear Weapons Surety, the AF Space Command Independent Strategic Advisory Group, the US Strategic Command Strategic Advisory Group and the Missile Defense White Team. In addition, he is a member of the Defense Science Board, the Missile Defense Agency Advisory Committee, the US Joint Forces Command Transformation Advisory Group, the Council on Foreign Relations, the Atlantic Council, the Lawrence Livermore National Laboratory Director's Review Committee, and the Los Alamos and Lawrence Livermore National Laboratories Mission Committee.

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DSSG
Defense Science Study Group

DSSG Alumni

DSSG I (1986-1989)

Russel E. Caflisch University of California, Los Angeles
Stephen Case†
Vicki L. Chandler Minerva Schools at KGI
Katherine T. Faber California Institute of Technology
Bruce E. Hajek University of Illinois at Urbana-Champaign
Deborah A. Joseph University of Wisconsin, Madison
Randy H. Katz University of California, Berkeley
Steven E. Koonin Center for Urban Science and Progress
Fredrick K. Lamb University of Illinois at Urbana-Champaign
Nathan S. Lewis California Institute of Technology
Philip S. Marcus University of California, Berkeley
Thomas F. Rosenbaum California Institute of Technology
Steven J. Sibener University of Chicago
Daniel L. Stein New York University
Warren S. Warren Duke University
R. Stanley Williams Hewlett-Packard Enterprise
W. Hugh Woodin University of California, Berkeley

DSSG II (1989-1991)

Stephen P. Boyd Stanford University
Stephen A. Campbell University of Minnesota
Susan N. Coppersmith University of Wisconsin, Madison
Werner J. Dahm Arizona State University
Robert H. Davis University of Colorado at Boulder
Joseph S. Francisco University of Nebraska-Lincoln
Steven M. George University of Colorado at Boulder
James M. Howe University of Virginia
Daniel M. Nosenchuck Princeton University
Anthony T. Patera Massachusetts Institute of Technology
Thomas A. Prince California Institute of Technology
Stephen W. Semmes Rice University
Theodore A. Slaman University of California, Berkeley
Robert L. Whetten The University of Texas at San Antonio

DSSG III (1992-1993)

Peter Chen Laboratorium für Organische Chemie
William J. Dally Stanford University
Mark E. Davis California Institute of Technology
S. James Gates, Jr. University of Maryland
Nancy M. Haegel National Renewable Energy Laboratory

† deceased

Thomas C. Halsey ExxonMobil Upstream Research Company
Robert A. Hummel Potomac Institute for Policy Studies
Anne Myers Kelley University of California, Merced
Kevin K. Lehmann University of Virginia
David L. McDowell Georgia Institute of Technology
Gerald A. Navratil Columbia University
Robert A. Pascal, Jr. Tulane University
Dennis L. Polla Intelligence Advanced Research Projects Activity
Peter W. Voorhees Northwestern University

DSSG IV (1994-1995)

A. Paul Alivisatos Lawrence Berkeley National Laboratory
Gregory L. Baker†
Gaetano Borriello†
Kevin F. Brennan†
Jean M. Carlson University of California, Santa Barbara
S. Lance Cooper University of Illinois at Urbana-Champaign
John C. Doyle California Institute of Technology
Brent T. Fultz California Institute of Technology
Daniel E. Hastings Massachusetts Institute of Technology
William C. Johnson University of Virginia
Richard B. Kaner University of California, Los Angeles
Ann R. Karagozian University of California, Los Angeles
Stephen D. Kevan University of Oregon
Christopher S. Kochanek The Ohio State University
Clifford R. Pollock Cornell University
Gabriel Robins University of Virginia
Michael J. Shelley New York University

DSSG V (1996-1997)

Geoffrey A. Blake California Institute of Technology
Emily A. Carter Princeton University
Steven J. Franke University of Illinois at Urbana-Champaign
Alec D. Gallimore University of Michigan
Steven R. Hall Massachusetts Institute of Technology
Robert J. Hamers University of Wisconsin, Madison
James A. Hendler Rensselaer Polytechnic Institute
John A. Hildebrand University of California, San Diego
David E. Luzzi Northeastern University
Fulvio Melia University of Arizona
Roy R. Parker University of Colorado at Boulder
Joseph Pasquale University of California, San Diego
Mara G. Prentiss Harvard University

† deceased

Eugene H. Spafford Purdue University
Paul S. Weiss University of California, Los Angeles

DSSG VI (1998-1999)

L. Catherine Brinson Northwestern University
Daniel E. Gottschling Fred Hutchinson Cancer Research Center
Robert D. Grober Yale University
James R. Heath California Institute of Technology
Theresa D. Hernandez University of Colorado at Boulder
Mark D. Hill University of Wisconsin, Madison
Jack H. Jacobs Honeywell Defense
Dimitris C. Lagoudas Texas A&M University
Ronald C. McGlennen
Robin R. Murphy Texas A&M University
Richard M. Murray California Institute of Technology
Geoffrey C. Orsak Texas Research Alliance
Kristofer S.J. Pister University of California, Berkeley
William S. Rees, Jr. Efkairia, LLC
Michael J. Sailor University of California, San Diego
James M. Tour Rice University

DSSG VII (2000-2001)

Brian M. Argrow University of Colorado at Boulder
Steven L. Ceccio University of Michigan
Bradley F. Chmelka University of California, Santa Barbara
Vicki L. Colvin Brown University
Andrew D. Ellington The University of Texas at Austin
Edward W. Felten Office of Science and Technology Policy
Adele E. Howe Colorado State University
Antoinette M. Maniatty Rensselaer Polytechnic Institute
Daniel N. Rockmore Dartmouth College
Timothy P. Stearns Stanford University
Barry A. Stoddard Fred Hutchinson Cancer Research Center
Ian A. Waitz Massachusetts Institute of Technology
Edward T. Yu The University of Texas at Austin

DSSG VIII (2002-2003)

K. Suzanne Barber The University of Texas at Austin
Angela M. Belcher Massachusetts Institute of Technology
Linda J. Broadbelt Northwestern University
Alison Chaiken Stanford Linear Accelerator Center
Vincent H. Crespi The Pennsylvania State University

† deceased

Joseph M. DeSimone University of North Carolina at Chapel Hill
Francis J. Doyle, III Harvard University
Richard P. Draves Microsoft Systems
Brett P. Giroir Health Science and Biosecurity Partners, LLC
Kevin T. Kornegay Morgan State University
Steven R. Quake Stanford University School of Medicine
William A. Stein University of Washington
Phoebe L. Stewart Case Western Reserve University
Gregory N. Washington University of California, Irvine
Jennifer L. West Duke University

DSSG IX (2004-2005)

Ana I. Anton Georgia Institute of Technology
Valerie S. Ashby Duke University
Carla E. Brodley Northeastern University
Raymond J. Deshaies California Institute of Technology
Jonathan A. Eisen University of California, Davis
Kenneth A. Gall Georgia Institute of Technology
Anthony D. Joseph University of California, Berkeley
Catherine J. Murphy University of Illinois at Urbana-Champaign
Lynne E. Parker National Science Foundation
Daphne K. Preuss Chromatin Inc.
Darrell G. Schlom Cornell University
Robert J. Schoelkopf Yale University
Julie A. Theriot Stanford University School of Medicine
Dawn M. Tilbury University of Michigan

DSSG X (2006-2007)

Eric G. Blackman University of Rochester
Ronald R. Breaker Yale University
Paul S. Cremer The Pennsylvania State University
Kevin R. Fall Carnegie Mellon University
Melina E. Hale University of Chicago
John B. Hogenesch University of Cincinnati College of Medicine
David D. Jensen University of Massachusetts, Amherst
Thomas C. Killian Rice University
Tonya L. Kuhl University of California, Davis
Sarah H. Lisanby National Institutes of Health
Surya K. Mallapragada Iowa State University
Andrew D. Mesecar Purdue University
Eunice E. Santos Illinois Institute of Technology
Srinivasan Seshan Carnegie Mellon University
Minami Yoda Georgia Institute of Technology

† deceased

DSSG XI (2008-2009)

Andrew G. Alleyne University of Illinois, Urbana-Champaign
Adam P. Arkin University of California, Berkeley
Jennifer T. Bernhard University of Illinois, Urbana-Champaign
Matthew S. Bogyo Stanford University
Iain D. Boyd University of Michigan
Christopher S. Chen Boston University
Colin S. Duckett University of Michigan
David E. Evans University of Virginia
Stephen W. Keckler The University of Texas at Austin
David R. Liu Harvard University
Kevin M. Lynch Northwestern University
Christine Ortiz Massachusetts Institute of Technology
Floyd E. Romesberg The Scripps Research Institute
Clarence W. Rowley Princeton University
Daniel S. Wallach Rice University

DSSG XII (2010-2011)

Charles H. Ahn Yale University
Keren Bergman Columbia University
Paul V. Braun University of Illinois at Urbana-Champaign
Steven E. Brenner University of California, Berkeley
Paul J. Chirik Princeton University
Tom Chou University of California, Los Angeles
Warren E. Dixon University of Florida
Soha Hassoun Tufts University
John S. Heidemann University of Southern California
Grant J. Jensen California Institute of Technology
Douglas Natelson Rice University
Teri W. Odom Northwestern University
Lucy Y. Pao University of Colorado at Boulder
Neelesh A. Patankar Northwestern University
Jennifer L. Rexford Princeton University
Gregory N. Tew University of Massachusetts, Amherst
Ali Yazdani Princeton University

DSSG XIII (2012-2013)

Ella M. Atkins University of Michigan
Randal C. Burns The Johns Hopkins University
Mark E. Campbell Cornell University
Seth M. Cohen University of California, San Diego
Ryan L. Garibaldi IDA Center for Communications Research
David S. Ginger, Jr. University of Washington

† deceased

Jack Harris Yale University
Mitra J. Hartmann Northwestern University|
Anette E. Hosoi Massachusetts Institute of Technology
Galen A. McKinley University of Wisconsin, Madison
Alex C. Snoeren University of California, San Diego
Krystyn J. Van Vliet Massachusetts Institute of Technology
Sharon M. Weiss Vanderbilt University
Regan A. Zane Utah State University

DSSG XIV (2014-2015)

Ryan C. Bailey University of Illinois at Urbana-Champaign
Jacopo Buongiorno Massachusetts Institute of Technology
Manish J. Butte Stanford University
John O. Dabiri Stanford University
Matthew P. DeLisa Cornell University
Gregory S. Engel The University of Chicago
Gregory A. Fiete The University of Texas at Austin
Samuel Graham, Jr. Georgia Institute of Technology
Ayanna Howard Georgia Institute of Technology
Tadayoshi Kohno University of Washington
Jack J. McNamara The Ohio State University
Todd D. Murphey Northwestern University
Christina D. Smolke Stanford University
Michael S. Strano Massachusetts Institute of Technology
Douglas B. Weibel University of Wisconsin, Madison

DSSG XV (2016-2017)

Alán Aspuru-Guzik Harvard University
Andrew J. Baker Rutgers, The State University of New Jersey
Phil S. Baran The Scripps Research Institute
Brian L. DeMarco University of Illinois at Urbana-Champaign
David C. Erickson Cornell University
Ryan M. Eustice The University of Michigan
Jill S. Higginson University of Delaware
Andrew A. Houck Princeton University
Cherie R. Kagan University of Pennsylvania
Christy F. Landes Rice University
Michel M. Maharbiz University of California, Berkeley
Heather D. Maynard University of California, Los Angeles
Michael B. Miller University of California, Santa Barbara
Delia J. Milliron The University of Texas at Austin
Katherine A. Willets Temple University

† deceased

DSSG MENTORS

Admiral Charles S. Abbot, USN (Ret.) 2008-present
General Lew Allen, Jr., USAF (Ret.)† 1989-1988
Dr. Daniel Alpert 1986-1993
Dr. Richard M. Bernstein† 1986-1990
Dr. R. Stephen Berry 1986-1993
Dr. Mina J. Bissell 2000-2009
Admiral Dennis C. Blair, USN (Ret.) 2004-2008
Dr. D. Allan Bromley† 1994-1997
Dr. Solomon J. Buchsbaum† 1986-1993
Dr. Curtis G. Callan, Jr. 1994-1995
General Michael P.C. Carns, USAF (Ret.) 2000-present
Dr. Peter A. Carruthers† 1986-1988
General George W. Casey, Jr., USA (Ret.) 2012-present
General Kevin P. Chilton, USAF (Ret.) 2012-present
Dr. Ruth M. Davis† 1986-1999
Dr. John M. Deutch 1986-1988
General Russell Dougherty, USAF (Ret.)† 1989-1997
Dr. Delores M. Etter 1996-1999
Dr. Alexander H. Flax† 1986-2003
Dr. John S. Foster 1996-2009
Dr. Claire M. Fraser-Liggett 2002-2013
Dr. Eugene G. Fubini† 1986-1988
General Carlton W. Fulford, Jr., USMC (Ret.) 2004-present
The Honorable Preston M. Geren, III 2010-2015
General Andrew J. Goodpaster, USAF (Ret.)† 1986-2005
General Paul F. Gorman, USA (Ret.) 1989-1993
General Alfred M. Gray, USMC (Ret.) 1994-present
The Honorable Thomas F. Hall 2010-2013
Dr. William Happer 1994-1997
Dr. Daniel E. Hastings 2000-2001
Lieutenant General Randolph W. House, USA (Ret.) 2004-2007
Dr. William Jeffrey 2008-2009
General Hansford T. Johnson, USAF (Ret.) 2004-2013
Dr. Anita Jones 2002-2009
Dr. Ann P. Karagozian 2014-present
Admiral Isaac C. Kidd, Jr., USN (Ret.)† 1986-1993
Dr. Martha Krebs 1986-1993 & 2000-present
Dr. Steven E. Koonin 1992-1999 & 2012-present
Dr. Pater Lax 1986-1988
Mr. Philip L. Major 2000-2011
The Honorable John O. Marsh, Jr. 2000-2009
Ms. Barbara A. McNamara 2004-present
General Jack N. Merritt, USA (Ret.) 1998-2013
Dr. Jill P. Mesirov 2006-2009

† deceased

Dr. Julian C. Nall 1996-2007
Dr. John M. Palms 2002-present
Dr. Stanford S. Penner 1986-1993
Dr. David Pines 1986-1999
Dr. Mara G. Prentiss 2000-2013
Dr. William H. Press 1986-1988
General Bernard P. Randolph, USAF (Ret.) 1994-2001
Dr. Robert E. Roberts 1989-2001
Dr. Maxine L. Savitz 1994-1997
Admiral Leighton Smith, USN (Ret.) 2000-2003
General William Y. Smith,† USAF (Ret.) 1989-2013
Admiral Harry D. Train, III, USN (Ret.) 1989-2003
General Larry D. Welch, USAF (Ret.) 1991-present
Dr. Susan Wood 1998-1999
Dr. Joan B. Woodard 2012-present
Dr. Herbert F. York† 1986-1993 & 1996-1997

Directors

Robert E. Roberts	**1986-1988, 2012-present**
Leon R. Hirsch	**2008-2011**
Phil Gould†	**1998-2007**
William J. Hurley	**1996-1997**
Julian C. Nall	**1990-1995**
Rich Bergemann	**1989**

Program Administrators

Katie Gliwa	**2005-present**
Karen Olson	**2000-2005**
Nancy Licato	**1986-2000**

† deceased


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