Technology Leadership and Strategy Initiative

2011

Optimize & Resolve

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Council on Competitiveness

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TLSI Dialogue Series 2011: Optimize & Resolve
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Optimize.

Dialogue 5:
Ensuring U.S. Leadership in Strategic Technologies

July 14, 2011
Washington, D.C.

Letter from the President

On behalf of the Council on Competitiveness, it is my pleasure to release *Optimize*, the fifth report of the Technology Leadership and Strategy Initiative (TLSI). The TLSI convenes technology leaders from America's premier companies, universities and laboratories to energize America's research enterprise, lead in strategic technologies and apply technology wisely to the nation's greatest challenges.

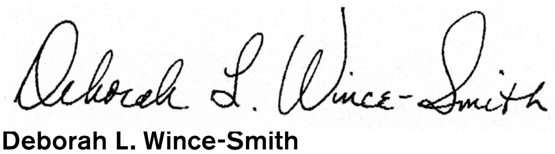
The initiative is led by Ray Johnson, senior vice president and chief technology officer of the Lockheed Martin Corporation; Mark Little, senior vice president and director of GE Global Research for the General Electric Company; and Klaus Hoehn, vice president, advanced technology and engineering for Deere & Company.

This report weaves together two parts. Part one set the stage for the dialogue. This "pre-report" analyzes the federal research enterprise, explains how the federal government sets research and innovation policy, and reviews current technology initiatives. Part two captures the ideas put forward in the fifth TLSI Dialogue held July 14, 2011, in Washington, DC.

The Dialogue featured leaders from the Department of Energy and asked participants to share ideas on how to improve federal decision-making. Participants also heard updates from the TLSI Working Groups, shared ideas about high performance computing, and identified strategic technologies that are critical to America's economy and security.

The Council also expresses its sincere thanks the U.S. Department of Defense for its support. The Council is committed to help the Department bring new technologies into practice faster and more efficiently—thereby strengthening America's industrial base and our national and economic security. The TLSI dialogues are designed to be an open exchange of ideas. The opinions and positions presented in this report are those of the Council or the individual who offered them. The opinions and positions in the report do not reflect official positions of the Department of Defense or other government agencies.

Sincerely,



Deborah L. Wince-Smith
President & CEO
Council on Competitiveness

Part 1:
Setting the Stage for TLSI Dialogue 5

PART 1: SETTING THE STAGE FOR TLSI DIALOGUE 5

Introduction

In 1810, a small town bordered by Honey Creek was established in the west central portion of Ohio. New Carlisle, located a little north of Dayton, would be the birthplace a century later for a future scientist named Roy, born in June of 1910. Although New Carlisle remains a rural area to this day, technology innovation has dramatically reshaped life there, as it has most places in the world. Roy, a contributor to that innovation, entered life at the onset of perhaps the most innovative century in human history. Looking at a few aspects of American life in 1910 makes clear just how profound innovation has been in a single lifetime.

Jefferson Street in New Carlisle, Ohio circa 1910.

Start by considering transportation. In 1910, the transition was still underway to automobiles, and the horse remained the principal means of everyday transport as it had been for thousands of years. The Ford Motor Company, organized in 1903, was striving to make automobiles within the financial reach of most Americans. In 1910, Ford was one of about 200 car companies in the United States and sold about 19,000 Model T cars. By 1917, sales would rise to more than 783,000 cars.[1] In 2010, U.S. vehicle sales topped 11.8 billion[2] and Americans own more than two vehicles per household.[3]

Automobile ownership changed lives in many ways—altering where people could live and travel, how and what they ate, what jobs they held and what infrastructure was expected from their tax dollars. Consider the economic impact of cars and trucks not only from the viewpoint of vehicle manufacturers, but also from that of petroleum, parts, electronics, construction, glass, steel, plastics, radio, music, shipping, tourism, food and many other industries.

Cars altered environmental and sanitation concerns, eliminating animal waste and certain disease risks from city streets but eventually raising concerns about things like smog and carbon emissions. Gas-powered vehicles changed the way warfare had been conducted for centuries, making troops more mobile and replacing cavalry with tanks. Cars also are culture. Americans sing of *Little Deuce Coupes*, *Pink Cadillacs* and *Little Red Corvettes*. They thrill to NASCAR and watch movies like *American Graffiti*, *Bullitt*, or Pixar's animated *Cars* produced using high performance computing.

Another mode of transportation, aviation, also was in its infancy in 1910. The pioneering Wright brothers lived and worked in Dayton—a mere 17 miles from Roy in New Carlisle—took their famous first flight in North Carolina in 1903. Flight, too, would transform human activity dramatically over the next century.

1 Model T Ford Club of America. www.mtfca.com/encyclo/fdsales.htm

2 Ward's Automotive Group. wardsauto.com/keydata/

3 AutoSpies.com. *Study Finds Americans Own 2.28 Vehicles Per Household*. February 2008. www.autospies.com/news/Study-Finds-Americans-Own-2-28-Vehicles-Per-Household-26437/

Plunkett, right, reenacts discovery.

An equally amazing shift occurred in medicine. The average life expectancy for Americans in 1910 was 49.4 years for men and 51.8 years for women.[4] Today, those figures stand at 75.7 and 80.6 years, respectively. As a population, Americans are living 56 percent longer today than in 1910. Consider the top causes of death in 1910 versus today. Gone from today's list are three of the top five killers from a century before, including tuberculosis. Ironically, the year was 1910 when a Russian Jew named Selman Waksman immigrated with his family to the United States. Waksman became a professor of biochemistry and microbiology at Rutgers University. In 1943-44, Waksman developed streptomycin, the first antibiotic effective against tuberculosis. The discovery led to several anti-tuberculosis drugs and a 1952 Nobel Prize for Waksman. Tuberculosis has not been eradicated, but it is no longer the threat it once was.

So what about the budding scientist, Roy, back in New Carlisle? When Roy was born in 1910, his parents had no radio (commercial broadcasting began in 1920) and no television (the first U.S. commercial licenses were granted in 1941).

Roy's parents also almost surely did not own a refrigerator. Mechanical refrigeration was largely limited to breweries and meat packers at the time, most using ammonia compression systems. But many of the chemicals used posed toxic hazards.[5] Scientists began searching for alternatives.

Roy J. Plunkett left New Carlisle to attend Manchester College in Indiana and the Ohio State University, where he earned a Ph.D. in chemistry in 1936. He took a research position with DuPont and, in 1938, was experimenting with Freon refrigerants. One night, a sample had frozen into a whitish, waxy solid. Rather than discard the apparent mistake, Roy and his assistant tested the new polymer and found that it had some very unusual properties: it was extremely slippery as well as inert to virtually all chemicals, including highly corrosive acids. The product, trademarked as Teflon in 1945, was first used by the military in artillery shell fuses and in the production of nuclear material for the Manhattan Project. After World War II, DuPont found a wide range of uses for Teflon, such as electrical cable insulation, soil and stain repellent for fabrics, and coating for non-stick cookware.[6] It remains a major product to this day.

The story of Roy Plunkett weaves together many elements that are still important components of America's innovation system. Plunkett credited his university education for the insight and ability to examine rather than discard the errant sample of Freon. A private firm, DuPont, brought Teflon to market. The government, through the U.S. military, supplied the initial market.

4 Congressional Research Service compilation from the *National Center for Health Statistics, National Vital Statistics Report, United States Life Tables, 2002*. November 2004.

5 Krasner-Kait, Barbara. *The Impact of Refrigeration*. History Magazine. www.history-magazine.com/refrig.html

6 E.I. du Pont de Nemours and Company. *Roy J. Plunkett: 1938*. www2.dupont.com/Heritage/en_US/1938_dupont/1938_indepth.html

Leading Causes of Death

1910	Today
1. Heart disease	1. Heart disease
2. Pneumonia and influenza	2. Cancer (malignant neoplasms)
3. Tuberculosis	3. Chronic lower respiratory disease (e.g. emphysema or chronic bronchitis)
4. Diarrhea, enteritis, and ulceration of the intestines	4. Stroke (cerebrovascular diseases)
5. Stroke (intracranial lesions of vascular origin)	5. Accidents

In Roy's lifetime, America literally moved from a horse and buggy to a space shuttle society. Innovation spawned industries that grew America's economy larger than any other and offered its citizens by many measures the highest standard of living in the world. When Roy passed away in 1994, the United States was on the precipice of another innovation revolution centered on information technologies. Libraries and the Dewey Decimal System (devised by American Melvil Dewey in 1876) would soon give way to the Internet and search engines…moving access to information from the technology of Gutenberg to Google almost overnight.

The Council on Competitiveness strives to keep the United States strong economically and its citizens prosperous. The Technology Leadership and Strategy Initiative (TLSI) seeks to strengthen America's capacity to innovate through better public policy and more effective collaboration between key stakeholders. The TLSI also aims to marshal abilities to address great challenges and lead in strategic technologies. Succeeding in these objectives will go a long way to securing another century of American innovation, productivity and higher living standards.

PART 1: SETTING THE STAGE FOR TLSI DIALOGUE 5

Overview of National Research Planning and Strategic Activities

Throughout the TLSI Dialogues, participants have suggested many ways to improve America's research and innovation enterprise. The Council would like to leverage the fifth dialogue in July 2011 to examine two broad questions: (1) how can U.S. leadership in strategic technologies and solutions to grand challenges be ensured, and (2) how can greater commercial and societal value from public R&D investment be generated while preserving a strong government role in frontier research?

Although the questions are interlinked, the first speaks to deciding which technologies and challenges are most important to America's future. The second question speaks to improving the management, rules and funding allocation of the federal research enterprise in order to address the priorities.

To facilitate the fifth dialogue, this report will offer information about the federal research enterprise, about the process by which a federal strategy is set, and snapshots of several initiatives designed to lead in strategic technologies or to address grand challenges.

The Federal Research Enterprise

In the report preceding the third TLSI Dialogue, the Council presented data on the roles of industry, academia and government in America's research enterprise. The report states that industry performs 73 percent of all American R&D and funds 67 percent. Government is the overwhelming source of basic research funding (57 percent), and academia is the top performer of basic research (56 percent). The report also broke down the latest available data on R&D funding by agency and the nature of the R&D performed (basic, applied or development)—see figure 1.

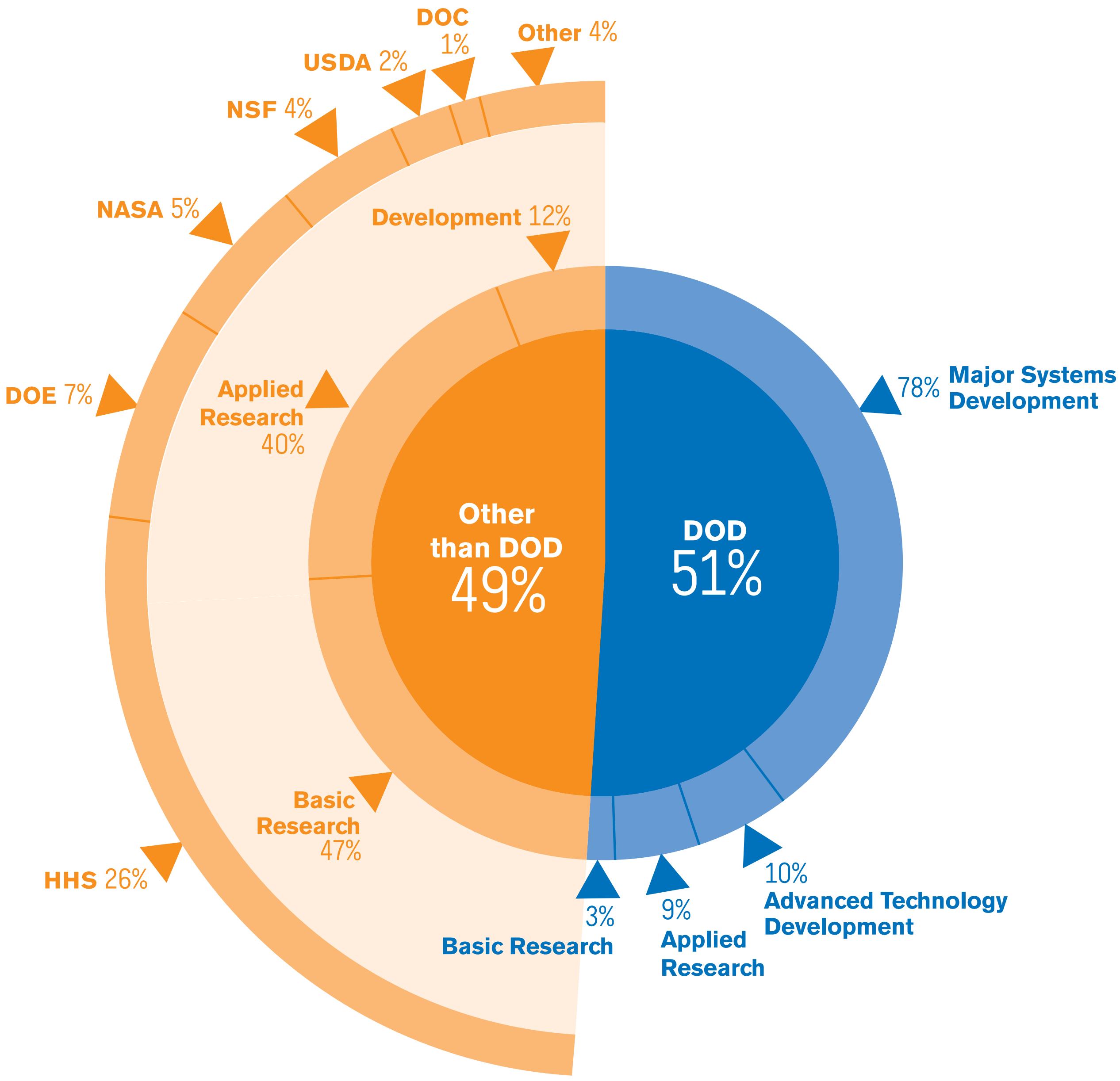
Figure 1 offers a helpful breakdown of funding by agency, but further insight can be gleaned by looking across the budget functions of the U.S. government. Federal spending is categorized by approximately 20 functions that cut across agencies. In many cases, R&D activities within multiple agencies support these functions—see figures 2 and 3.

This data make clear that, for example, six agencies play a role in research related to natural resources and environment, and that the Department of Energy (DOE) has research missions related not only to energy, but to national defense and to general science/basic research. The quantitative data in figure 3 indicate that roughly 77 percent of federal research investment (including equipment and facilities, or "plant") is devoted to national defense and health purposes, while less than 2 percent is devoted to energy. Note that figure 3 presents research funding priorities proposed by the president, not final funding appropriated by Congress.

The budget function analysis lends a sense of America's priorities and/or a relative perceived cost of achieving them. The analysis is not perfect, however. General science and basic research supported by the National Science Foundation (NSF), for example, is devoted for many purposes that intersect with other functions. Similarly, the Department of Defense (DOD) mission is broad enough that it sparks innovation beyond what might fall exclusively within a national defense category.

One illustration would be the DOD working with the DOE to advance mobility and strike capabilities, increase energy reliability on bases and improve institutional cooperation between the departments. The departments have partnered to test micro grids,

Figure 1. Projected Federal Obligations for R&D, by Agency and Character of Work, 2008
Source: National Science Foundation, Science and Engineering Indicators, 2010



DOC = Department of Commerce; DOD = Department of Defense; DOE = Department of Energy; HHS = Department of Health and Human Services; NASA = National Aeronautics and Space Administration; NSF = National Science Foundation; USDA = Department of Agriculture

Note: Detail may not add to total because of rounding.

Figure 2. Agency R&D Activity by Budget Function

Source: National Science Foundation, October 2010, drawn from agency submissions to OMB

Agency	Justice	Agriculture	Commerce and Housing Credit	Community & Regional Development	Education, training, employment and social services	Energy	General Science and Basic Research	Health	Income Security	International Affairs	Medicare	National Defense	National Resources and Environment	Space Research and Technology	Transportation	Veterans Benefits and Services
Agency for International Development										●						
Army Corp of Engineers (Civil)													●			
Department of Agriculture		●		●		●							●			
Department of Commerce			●										●			
Consumer Product Safety Commission								●								
Department of Defense (Military)												●				
Department of Education					●											
Department of Energy						●	●					●				
Dept. of Health and Human Services					●			●	●		●					
Department of Homeland Security	●						●						●		●	
Dept. of Housing and Urban Dev.				●												
Department of the Interior													●			
Department of Justice	●											●				
Department of Labor								●								
Department of State										●						
Department of Transportation															●	
Department of Veterans Affairs																●
Environmental Protection Agency													●			
International Security Assistance										●						
National Aeronautics and Space Adm.														●	●	
National Science Foundation							●									
Nuclear Regulatory Commission						●										
Smithsonian Institution					●											
Social Security Administration									●							
Telecom Development Fund			●													
Tennessee Valley Authority						●										

Figure 3. R&D by Budget Function and Share of Total Federal R&D

Source: National Science Foundation, Science and Engineering Statistics, 2011

Budget Function	FY11 Proposed Federal R&D and R&D Plant	Percent Total Proposed Federal R&D and R&D Plant
ALL FUNCTIONS CONDUCTING R&D	**148,019**	**100.00**
National defense	82,228	55.18
Health	32,067	21.52
General science and basic research	11,055	7.42
Space research and technology	9,911	6.65
Natural resources and environment	2,684	1.80
Energy	2,549	1.71
Transportation	2,071	1.39
Agriculture	2,054	1.38
Veterans benefits and services	1,180	0.79
Commerce and housing credit	775	0.52
Education, training, employment, and social services	634	0.43
International affairs	255	0.17
Community and regional development	233	0.16
Administration of justice	203	0.14
Income security	77	0.05
Medicare	42	0.02

alternative fuels, batteries and energy storage.[7] Succeeding in this work would have clear spill over benefits for non-defense national priorities.

The collaboration makes military and economic sense as the Pentagon strives for more resiliency and effectiveness at lower cost. The DOD is the biggest single energy consumer in the United States, spending $15 billion on fuel last year. Approximately 80 percent of the convoys in Afghanistan are devoted to carrying fuel.[8]

Even with such caveats, however, the data offer a reasonable snapshot of how federal research dollars are distributed among national priorities. Looking at this data over time, the TLSI Dialogue 3 report chronicled how defense and health research dollars have risen since the late 1990s, while R&D in other functions have remained flat or declined slightly.

The Obama administration has advocated a recalibration of the federal research portfolio (figure 4) to reflect its priorities in clean energy, general science, space and infrastructure. Although the percentage increase proposed for some of the priorities is large, recall that R&D increases to budget functions like energy and transportation would be from a smaller base of dollars.

Severe budgetary conditions are forcing the administration and Congress to make difficult choices. The president's total FY 2012 budget for R&D was $401 million, below (-0.3 percent) FY 2010 enacted levels, with pro-posed cuts in defense R&D offset by investment in non-defense priorities.[9]

Even these levels will be challenging to maintain. R&D funding declined in FY 2011, although less so than many other forms of discretionary spending. Congress undoubtedly will alter the president's FY 2012 proposal and enact legislation that reflects its priorities, driven not only by views related to R&D, but also to the larger fiscal environment. Although support for R&D is bipartisan generally, House majority members have indicated concerns with the president's proposed investment increases in green energy and applied research. Other members have sought deeper cuts in research budgets across the board or mandates to eliminate funding for "lowest-performing awards" in basic research.

Development of Federal Research and Innovation Strategies

Within the executive branch, federal research and innovation policy is largely set by individual agencies determining how to achieve their missions and fulfill their statutory requirements. Agency funding and policy proposals are vetted through the process of developing the president's budget. At a macro level across the agencies, the White House's Office of Science and Technology Policy (OSTP) and the Office of Management and Budget (OMB) offer strategic oversight to ensure that presidential priorities are addressed and that cross-agency initiatives are coordinated.

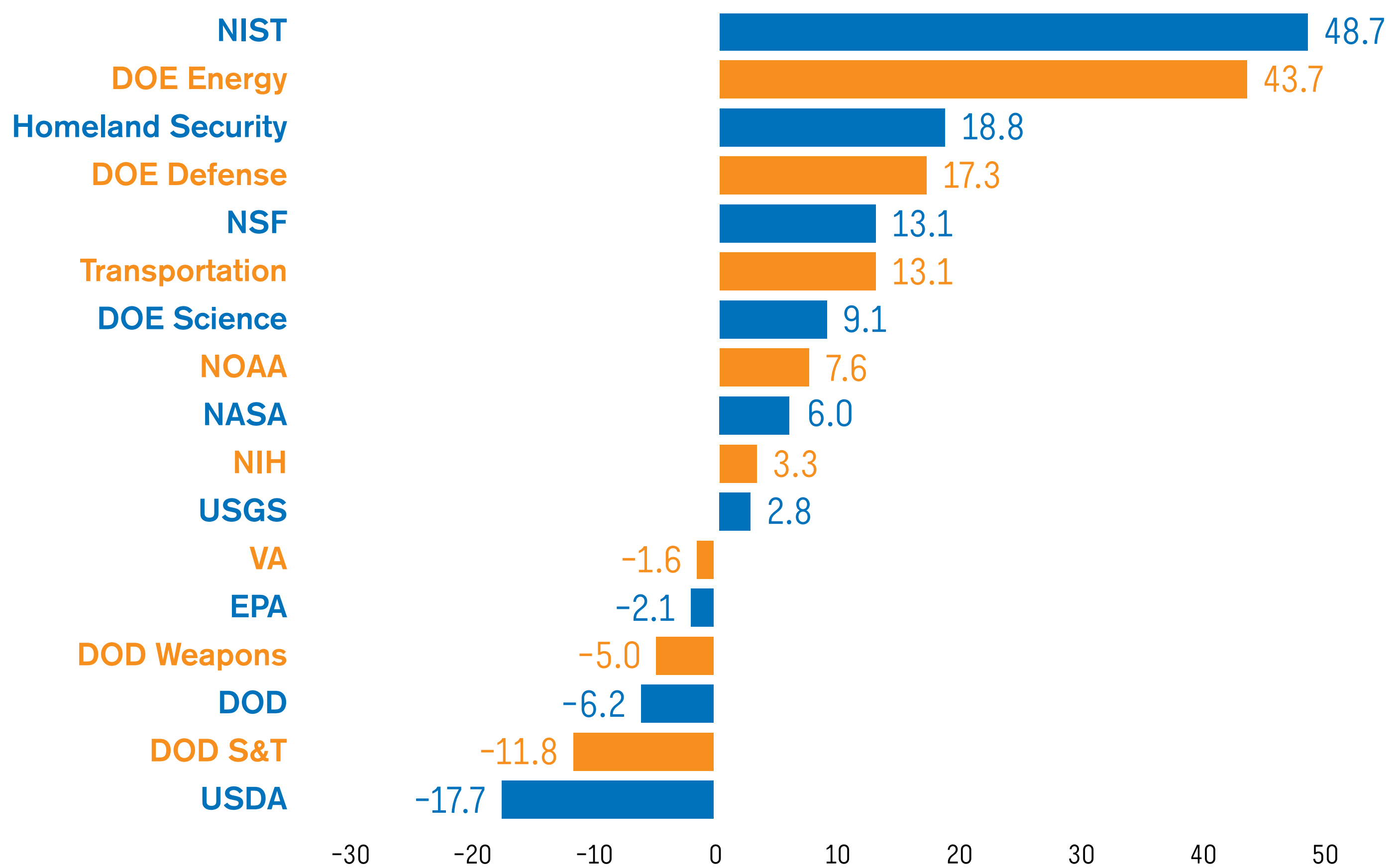
OSTP oversees the National Science and Technology Council (NSTC), a body made up of 27 cabinet secretaries, agency heads and White House officials with significant science and technology responsibilities. The NSTC is charged with setting national goals

7 Weisgerber, Marcus. ***Energy Rises as Pentagon Priority***. DefenseNews. April 26, 2011. http://www.defensenews.com/story.php?i=6333757

8 Johnson, Keith. ***Pentagon's First Energy Plan***. Wall Street Journal. June 15, 2011.

9 American Association for the Advancement of Science. *AAAS Report XXXVI, Research & Development FY 2012*. pp. 8-9.

Figure 4. FY 2012 R&D Budget Request—Percent Change from FY 2010 Enacted
Source: American Association for the Advancement of Science, 2011



and strategies for federal science and technology. Its primary committees are: (1) science, (2) technology, (3) homeland and national security, and (4) environment, natural resources and sustainability. Informing the president and OSTP is a group of leading American scientists and engineers, the President's Council of Advisors on Science and Technology (PCAST).

Congressional oversight of R&D is fragmented into several silos (committees of jurisdiction), with few tools to coordinate across missions or agencies. The House Science and Technology Committee and the Senate Commerce, Science and Transportation Committee are the main, but not the exclusive, authorization committees that oversee R&D programs. Authorization committees establish the legislative rules that govern programs and authorize funding levels.

The House and Senate appropriations committees determine the actual resources available to agencies and programs. The appropriations committees are divided into 12 subcommittees that determine a portion of the budget. Eleven of the 12 subcommittees have R&D components (figure 5). Four subcommittees oversee 95 percent of the R&D proposed for FY 2012: (1) defense; (2) labor, HHS and education; (3) commerce, justice and science; and (4) energy and water.

Figure 5. R&D Funding by Congressional Appropriations Subcommittee
Source: American Association for the Advancement of Science

			Change FY 2010-2012	
	FY 2010 Actual	FY 2012 Budget	Amount	Percent
Defense	82,833	77,649	-5,183	-6.3
Labor, HHS, Education	31,547	32,782	1,235	3.9
Commerce, Justing, Science	16,070	17,761	1,691	10.5
Energy and Water	10,959	13,108	2,149	19.6
Agriculture	2,491	1,950	-541	-21.7
Interior and Environment	2,020	1,985	-35	-1.7
Military Construction, VA	1,103	1,122	19	1.7
Transportation, HUD	1,185	1,285	100	8.4
Homeland Security	887	1,054	167	18.8
State and Foreign Operations	194	196	2	1.0
Financial Services	7	2	-5	-71.4
Total R&D	149,295	148,894	-401	-0.3

The subcommittees act largely independently of each other and research programs compete with non-research programs within a bucket of funding (a subcommittee allocation) set by the House and Senate budget committees. The result is that it is difficult to coordinate research funding across the jurisdictional silos or to shift funding from one research program to another if they are not governed by the same subcommittee.

PART 1: SETTING THE STAGE FOR TLSI DIALOGUE 5

Initiatives to Lead in Strategic Technologies and Address Grand Challenges

A national innovation strategy, however, encompasses more than the R&D budgetary blueprints of the executive and legislative branches of government. In February 2011, the administration issued an updated *Strategy for American Innovation*. The strategy identifies funding priorities within a larger framework to reform key policies, lead in strategic technologies and address grand challenges (figure 6).

Key Policies: Many of the policy issues identified by the TLSI are the focus of recent administration proposals, both in and out of the *Strategy for American Innovation*. Examples include proposals to reshape high-skill immigration rules, export controls, the patent system and the R&D tax credit. As the TLSI moves toward issuing a end-of-year report in late 2011, participants will consider the status and content of these proposals and suggest additional reforms.

Figure 6. Strategy for American Innovation, February 2011
Source: National Economic Council, Council of Economic Advisors, Office of Science and Technology Policy

Strategic Technologies: The administration's strategy emphasizes several technology areas, including biotechnology, nanotechnology, alternative energy, space, education and health-related technologies. Biotechnology and nanotechnology are particularly strategic because they are broad-based disciplines with over-arching applications for business and government. The National Nanotechnology Initiative (NNI) and the Networking and Information Technology Research and Development (NITRD) program are perhaps the clearest examples of a cross-agency efforts to ensure that America remains a leader in critical technology fields.

Launched in 2000, the NNI consists currently of 25 federal agencies with research and regulatory responsibilities related to nanotechnology. The NNI aims to move nanotechnology discoveries from the laboratory into new products for commercial and public benefit, encourage more students and teachers to become involved in nanotechnology education, create a skilled workforce and the supporting infrastructure and tools to advance nanotechnology and to support the responsible development of nanotechnology.[10] Activities are broken into eight subjects, or program component areas (figure 7).

In FY 2011, NNI activities received $1.85 billion in funding. The National Institutes of Health supplied the largest share of funding ($457 billion, or about 25 percent). The other major funders include the NSF, the National Institute for Standards and Technology (NIST), and the DOD and DOE. Together, these five agencies accounted for 95 percent of all NII resources.[11] The president's FY 2012 budget proposes $2.13 billion for NNI activities, with a substantial increase proposed for the DOE.

Nanotechnology promises to transform multiple industries: capturing and storing clean energy, developing next-generation computer chips, allowing early detection of diseases, creating smart anti-cancer therapeutics that deliver drugs only to tumor cells, and enabling all-new approaches to a wide range of manufacturing activities…

While the commercial impact of nanotechnology to date has been limited primarily to nanomaterials applied to a range of consumer goods from healthcare and food products to textiles, automotive composites and industrial coatings, nanotechnology innovation is beginning to accelerate.

Excerpt from *Strategy for American Innovation*

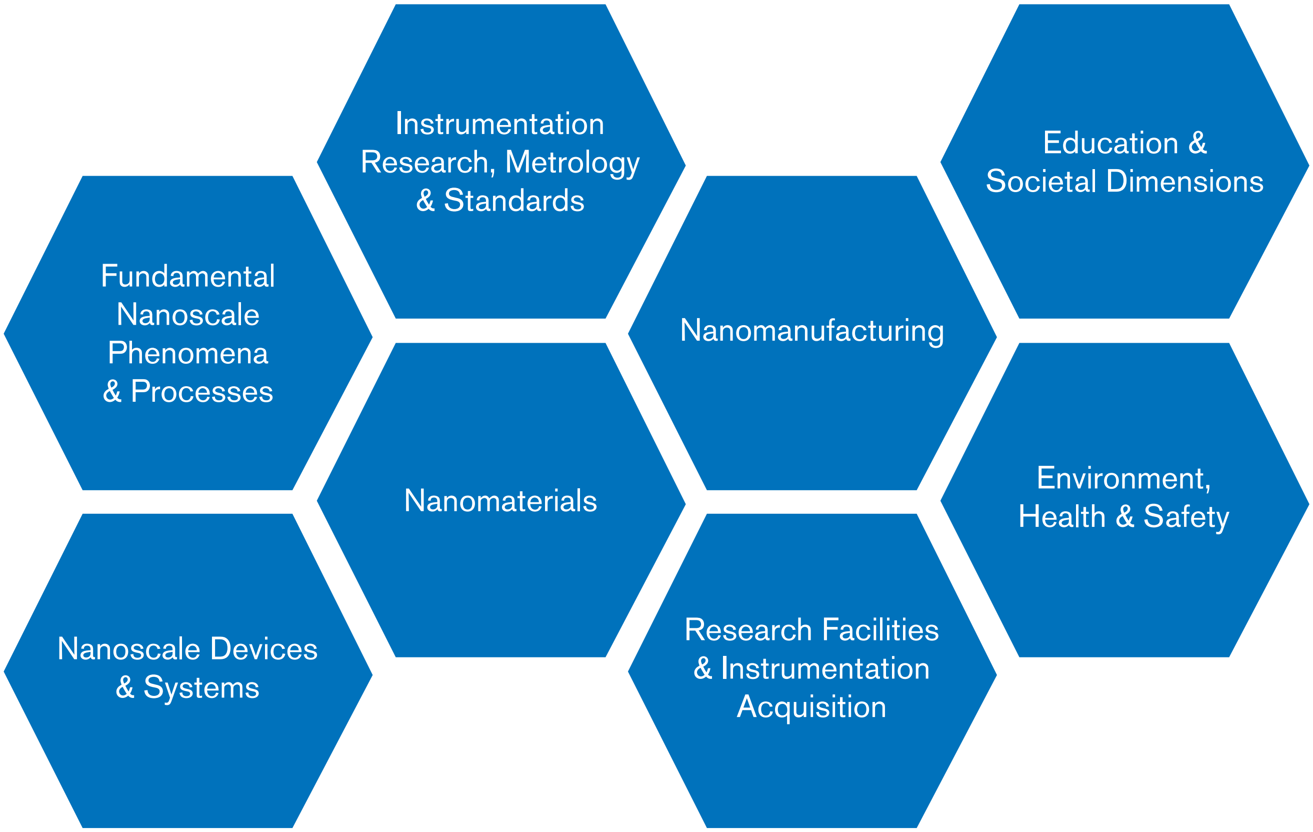
The NITRD program coordinates federal interests and actions in advanced information technologies such as computing, networking and software. The NITRD program seeks to accelerate the development and deployment of these technologies "in order to maintain world leadership in science and engineering; enhance national defense and national and homeland security; improve U.S. productivity and competitiveness and promote long-term economic growth; improve the health of the U.S. citizenry; protect the environment; improve education, training, and lifelong learning; and improve the quality of life."[12]

10 National Nanotechnology Initiative. http://www.nano.gov/about-nni/what/vision-goals

11 National Nanotechnology Initiative. http://www.nano.gov/about-nni/what/funding

12 Networking and Information Technology Research and Development Program. http://www.nitrd.gov/about/about_nitrd.aspx

Figure 7. National Nanotechnology Initiative, Program Component Areas



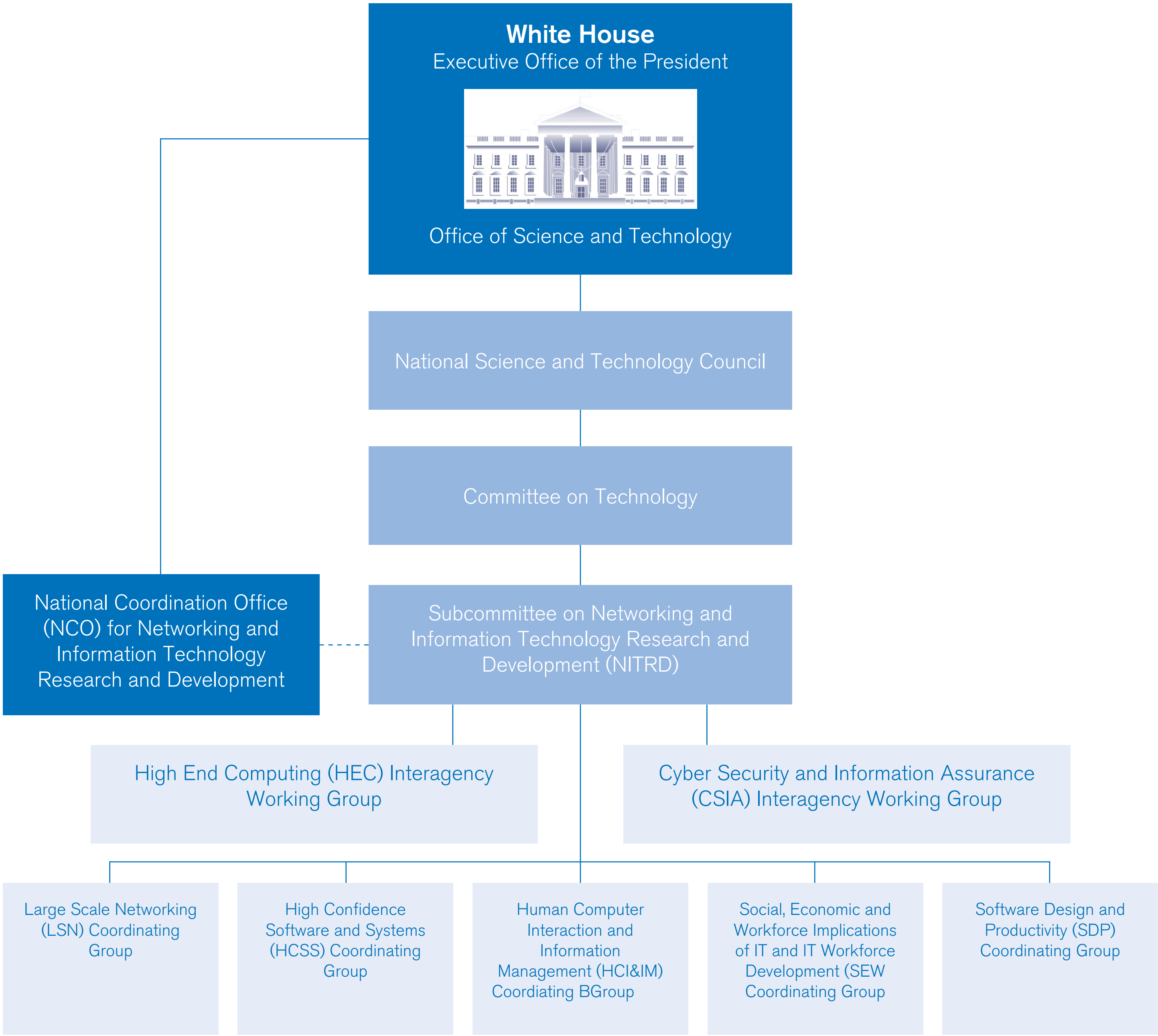
Fifteen federal agencies participate under one or both of the NITRD program's interagency working groups. One working group is responsible for cyber security and information assurance, and the other is centered on high-end computing. NITRD also utilizes coordinating groups for cross-cutting issues and a coordination office to manage research and development activities (figure 8). The president has requested $3.9 million in total funding across all agencies for NITRD activities in FY 2012.

Grand Challenges: Most technology focal points of the administration's *Strategy for American Innovation* fall under grand challenges rather than arch over them—challenges such as energy, health, education and leadership in space technology. Prior TLSI reports have noted elements of defense and homeland security technology strategies. Additional government strategies with significant technology components include those centered on challenges like food security and critical materials. This section offers brief sketches of the responses to some of these challenges.

ENERGY: The Obama administration has pursued an aggressive strategy on several fronts to accelerate alternative energy development and deployment. The initiatives aim to reduce risks associated with climate change, make the United States more energy self-reliant, and ensure that American firms capture leading positions in emerging and future global energy markets.

Figure 8. NITRD Program Coordination

Source: http://www.nitrd.gov/subcommittee/NITRD-Org-Chart_121608.pdf



The *Strategy for American Innovation* highlights several components of this work, including:

- **Renewable energy like solar, wind and geothermal technologies.** The administration has used tax credits and financing support to encourage greater power generation from these sources. Officials project that the administration's goal to double 2008 levels of renewable generation by the end of 2012 will be achieved.
- **Energy Innovation Hubs.** The administration has established three Energy Innovation Hubs to tackle challenges in nuclear energy modeling (Oak Ridge, TN), energy efficiency in buildings (Philadelphia), and the generation of fuel from sunlight (Pasadena, CA). The administration's FY 2012 budget calls for three more hubs to tackle additional energy challenges. The hubs concentrate funding to bring together scientists and thinkers from different disciplines in integrated research teams.

  The hub in Philadelphia also became the first Energy Regional Innovation Cluster, drawing on resources from six additional agencies to help achieve its mission. The Philadelphia cluster is slated to receive $129 million in federal funding over five years and $30 million in state support. Other contributors and participants include 11 academic institutions, two national laboratories, five major industry partners and regional economic development agencies.
- **ARPA-E.** The Energy Department's Advanced Research Projects Agency-Energy (ARPA-E) seeks to overcome long-term and high-risk technological barriers to achieve major energy breakthroughs. The agency has awarded nearly $400 million to more than 100 research projects. ARPA-E projects fall under strategic programs (figure 9) and aim to achieve specific price and/or performance metrics that will enable the technologies to transition to commercial use without federal subsidies. One grant, for example, is to develop a battery that would enable a car to travel 300 miles on a single charge.

HEALTH: As with energy, there are more health care initiatives underway than can be can be covered in this report, so featured here are the priorities highlighted in the administration's innovation strategy—DNA sequencing, health IT and device advances. Somewhat apart from the larger cost and coverage debates associated with the health care system, there is a great deal of consensus around driving innovation in these areas.

- **DNA Sequencing.** The federal government is leveraging Recovery Act funds at NIH to invest in the sequencing of more than 1,800 complete genomes, a more than 50-fold increase over the 34 genomes that had been sequenced as of February 2011. The effort seeks to gain insight into major diseases while also driving down sequencing costs. NIH also is leading the Cancer Genome Atlas, the most comprehensive analysis of the molecular basis of cancer undertaken, which may unleash new possibilities for treatment, diagnosis and personalized care.
- **Health IT.** Information technology still has great potential to revolutionize the health care system by offering tools to lower costs, reduce errors and increase the quality of care. The Office of the National Coordinator for Health Information Technology is promoting IT adoption through several initiatives related to electronic health records, standards for health information exchange over the Internet and mobile health technologies. In addition, the Strategic Health IT Advanced Research Projects Program funds potentially game-changing advances to address problems that have impeded adoption of health IT.
- **Medical Device Technology.** The U.S. Food and Drug Administration (FDA) launched a transparency initiative in 2009 to improve the

Figure 9. ARPA-E Programs
Source: www.arpa-e.energy.gov

BEEST

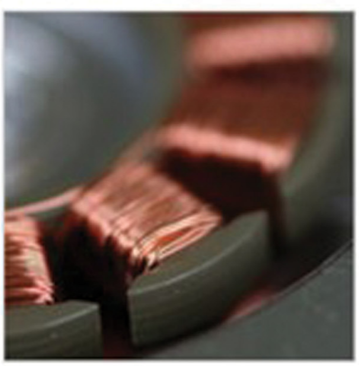
Better batteries will encourage public adoption of electric vehicles and shift transportation energy reliance from oil to the domestically-powered U.S. electric grid.

IMPACCT

IMPACCT aims to revolutionize technologies that prevent carbon dioxide produced by coal-fired power plants from entering the atmosphere and contributing to global warming.

GRIDS

GRIDS explores new technologies that enable widespread use of cost-effective grid-scale energy storage and balance the short-duration variability in renewable generation.



ADEPT

ADEPT explores materials for key advances in soft magnetics, high-voltage switches, and reliable, high-density charge storage that will reduce energy costs and consumption.

Electrofuels

ARPA-E seeks to use microorganisms to harness energy and convert carbon dioxide into liquid fuels. Theoretically, this could be10 times more efficient than current approaches.

BEETIT

ARPA-E seeks to develop energy-efficient building cooling technologies that will reduce energy consumption and GHG emissions.

market's understanding of the approval process and encourage innovation. In 2010, the FDA created the Council on Medical Device Innovation, designed to identify unmet public health needs and encourage innovation to address them.

FOOD SECURITY: It has been estimated that providing sufficient food to the world's growing population will require a 70 percent increase in agricultural production by 2050. To meet this challenge under constraints of limited agricultural land availability, increased climatic variability and scarce water supplies, the world will need scientific and technological innovations that increase agricultural productivity and improve the availability of nutritious foods.[13]

"Consumption of the four staples that supply most human calories—wheat, rice, corn and soybeans—has outstripped production for much of the past decade, drawing once large stockpiles down to worrisome levels. The imbalance between supply and demand has resulted in two huge spikes in international grain prices since 2007, with some grains more than doubling in cost. Those price jumps, though felt only moderately in the West, have worsened hunger for tens of millions of poor people, destabilizing politics in scores of countries."[14]

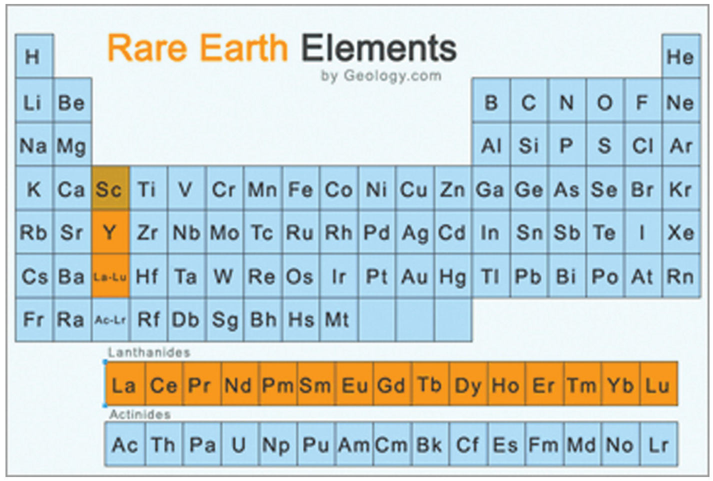
Food security is foremost a humanitarian issue, but it is also an economic challenge and opportunity. It is a challenge when markets are destabilized or the discretionary income of millions of people disappears in an effort to obtain food. It is an opportunity for food and food equipment producers inside and outside of the United States to create new markets in crops, livestock and aquaculture.

Developed jointly by the U.S. Agency for International Development and the U.S. Department of Agriculture, the federal government's Feed the Future Research

13 U.S. Agency for International Development and U.S. Department of Agriculture. *Feed the Future: Global Food Security Research Strategy*. May 2011.

14 Gillis, Justin. *A Warming Planet Struggles to Feed Itself.* New York Times. June 4, 2011.

Figure 10. Critical (Rare Earth) Elements
Source: Geology.com



Strategy is a component of the broader Feed the Future Initiative. The proposed $145 million research portfolio (FY 2012) aims to create more productive crops, intensify agricultural production systems, ensure food security, and enhance access to nutritionally improved diets. The proposed FY 2012 budget for the entire Feed the Future Initiative is $1.1 billion.

CRITICAL (RARE EARTH) MATERIALS: Rare earth materials are a group of seventeen elements (figure 10). The group consists of yttrium and the 15 lanthanide elements (lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium and lutetium). Scandium is found in most rare earth element deposits and is sometimes classified as a rare earth element. The rare earth elements are all metals.[15]

Rare earth metals and alloys that contain them are used in devices such as computer memory, DVDs, rechargeable batteries, cell phones, catalytic converters, magnets, fluorescent lighting and much

15 Geology.com. http://geology.com/articles/rare-earth-elements/

Figure 11. Defense Uses of Rare Earth Elements
Source: Geology.com

Lanthanum	Night-vision goggles
Neodymium	Laser range-finders, guidance systems, communications
Europium	Fluorescents and phosphors in lamps and monitors
Erbium	Amplifiers in fiber-optic data transmission
Samarium	Permanent magnets that are stable at high temperatures Precision-guided weapons "White noise" production in stealth technology

more. Several pounds of rare earth compounds are used in batteries for electric and hybrid-electric vehicles.[16] Wind turbines, photovoltaic cells and fluorescent lighting also rely on these materials, as do many important defense capabilities (figure 11).

China produces 97 percent of all rare earth elements consumed in the world today and continues to restrict the export of these materials.[17] The United States has challenged the export restrictions through the World Trade Organization. Congress also is taking up the issue, and legislation has been proposed in the House and Senate. Congress has already required the DOD to assess rare earth supply chain issues and develop and plan to address them as needed.

Rare earth elements are not as "rare" as their name implies, however. Thulium and lutetium are the two least abundant rare earth elements, but they each have an average crustal abundance that is nearly 200 times greater than that of gold. However, the metals are very difficult to mine because it is unusual to find them in concentrations high enough for economical extraction.[18]

In order to address the Chinese monopoly and in recognition of the role the metals play in the clean energy economy, the DOE released a critical materials strategy in December 2010. The study explores eight policies and program areas that could help reduce vulnerabilities and address critical material needs, including research and development; information-gathering; permitting for domestic production; financial assistance for domestic production; and processing, stockpiling, recycling, education and diplomacy. The report also promised to follow-up with a more complete U.S. rare-earth development strategy by the end of 2011.[19]

16 Ibid.

17 Folger, Tim. *The Secret Ingredients of Everything*. National Geographic Magazine. June 2011

18 Geology.com. http://geology.com/articles/rare-earth-elements

19 Das, Anil. *2011 Spells Desperate Search for Rare Earth Minerals*. International Business Times. January 8, 2011.

PART 1: SETTING THE STAGE FOR TLSI DIALOGUE 5

Questions for TLSI Participants

At each of the TLSI Dialogues, participants have examined various characteristics of the U.S. innovation system. The fifth dialogue seeks to explore a few basic questions:

1. How well do the U.S. policy-making structures operate across agencies for innovation and research issues? How might they be improved?
2. Does the United States have a reasonable balance within its innovation investment portfolio to achieve its most important missions? Where might it be out of balance, underfunded, or missing strategic technologies and challenges?
3. How might key initiatives, policies or programs be improved that aim to address strategic technologies and grand challenges?

PART 1: SETTING THE STAGE FOR TLSI DIALOGUE 5

Linkage between TLSI and U.S. Manufacturing Competitiveness Initiative

The Council has taken several steps in the first half of 2011 to integrate thinking between two of its key initiatives, the TLSI and the U.S. Manufacturing Competitiveness Initiative (USMCI). The TLSI will serve as the technology think tank for the USMCI. As part of this coordination, the chair of the TLSI Accelerating Innovation Working Group, Steve Ashby, hosted a USMCI "Out of the Blue" Dialogue at the Pacific Northwest National Laboratory. TLSI members also have participated in several USMCI dialogues across the country.

Several insights emerged from these conversations. Two prominent ideas are:

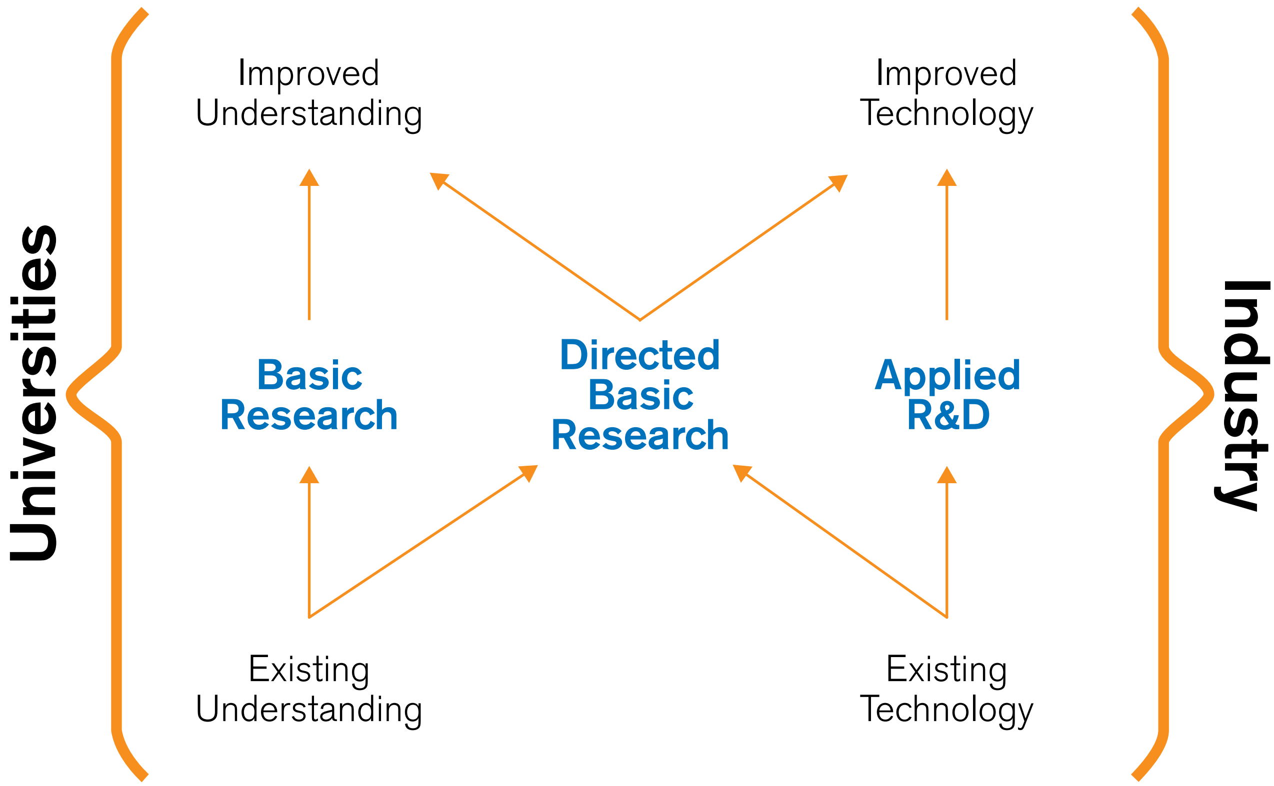
1. Two valleys of death exist on the path from new idea to production at scale. The traditional valley continues between a commercially viable idea and funding through the prototyping, regulatory approval and initial production stages. A second valley emerges at roughly the point of scaling up production beyond $150 million in revenue.[20] Many firms are finding it difficult to obtain capital or operate in a cost structure that is competitive with opportunities outside the United States. To capture the full fruits of the U.S. innovation ecosystem, Council members are considering ways Americans might bridge both valleys.
2. The early innovation process could be more informed by commercial and production considerations. TLSI and USMCI participants firmly support continued funding for curiosity-driven basic research at universities, but they are equally convinced that a greater share of federal basic research investment could be informed by the pull of national priorities or strategic technologies that would boost American competitiveness and create jobs.

The administration is taking beginning steps in this direction, proposing $75 million in FY 2011 for the Technology Innovation Program (TIP) that funds high-risk, high-reward research in areas of national need. TIP received $45 million in FY 2011, enough to fund existing projects, but no new ones.

The president's budget also includes $12 million in FY 2012 to launch an Advanced Manufacturing Technology Consortia (AMTech) program, a public-private partnership coordinated by NIST and designed to support advanced manufacturing R&D and reduce the time required for end-to-end innovation. AMTech aims to identify and develop platform technologies in collaboration with industry. NIST believes that AMTech could spur a change to the difficult transition between basic research and applied R&D—very much like TLSI participants have discussed (figure 12). The public-private consortia would serve to inform officials about high-potential, directed basic research in manufacturing technology that would not benefit a single firm, but could spur industry-wide advances and greater domestic production.

20 Council on Competitiveness U.S. Manufacturing Competitiveness Initiative and Deloitte

Figure 12. Creating a New Paradigm by Connecting Basic Science with Industrial Drivers
Source: Drawn from NIST Presentation on Advanced Manufacturing Technology Consortia Program



Working Group Progress

The report preceding the TLSI Dialogue 4 offered a detailed overview of the ideas being generated by the working groups. The groups—that have met, in toto, more than a dozen times during the past year—continue to meet to refine and prioritize those ideas, which will be presented in near final form at the October 24, 2011, TLSI Dialogue as the Council moves to issue final recommendations this year.

Figure 13 offers a high-level snapshot of the objectives being pursued in each group. Final recommendations will be of sufficient detail to be actionable and will be circulated to the larger TLSI for review. The Innovation Outreach Working Group will play a unique role in that it will help devise a strategy to take the TLSI recommendations to key policymakers and stakeholders across the country following the final report. The TLSI co-chairs have emphasized continually that the initiative's value lays not in its ideas, but in the implementation of those ideas.

Figure 13. Objectives Pursued by TLSI Working Groups

Part 2:
Findings from TLSI Dialogue 5

PART 2: FINDINGS FROM TLSI DIALOGUE 5

Opening Remarks

Deborah L. Wince-Smith, president & CEO of the Council on Competitiveness, welcomed participants to the dialogue and welcomed the co-chairs of the Technology Leadership and Strategy Initiative (TLSI). The co-chairs are Klaus Hoehn, vice president for advanced technology and engineering at Deere & Company, Ray Johnson, senior vice president and chief technology officer of the Lockheed Martin Corporation, and Mark Little, senior vice president and chief technology officer of the General Electric Company.

Wince-Smith reminded participants of the TLSI's importance in setting a technology agenda for the United States. She did so by offering insights from her recent meetings with senior Chinese officials who develop their nation's economic strategies. "A strategy on virtually every area of science and technology leadership is on a path and moving," Wince-Smith emphasized, "They are going to be formidable competitors as they already are, but I highlight their efforts as another reason why the work of the TLSI is so critical to the future of our nation."

Hoehn opened the dialogue for the co-chairs, sharing his views on U.S. competitiveness based on a 35-year career on three continents. He confirmed Wince-Smith's observations about how aggressively the rest of the world seeks to drive their competitiveness around technology innovation. "We have not woken up in this country to react to the hunger they have to establish their economies," Hoehn said. He noted the rapid growth of Chinese industry and the rising respect given to educational institutions like Beijing University.

Chad Evans, Council on Competitiveness; Klaus Hoehn, Deere & Company; Bart Gordan, K&L Gates and Council on Competitiveness; Arun Majumdar, ARPA-e; Deborah L. Wince-Smith, Council on Competitiveness; Ray Johnson, Lockheed Martin Corporation; and Mark Little, General Electric Company.

Hoehn complimented the TLSI and other Council initiatives on high performance computing and advanced manufacturing. He believes the initiatives are important and helping to shape the thinking of U.S. leaders, such as U.S. Energy Secretary Steven Chu, who Hoehn noted has indicated that he is willing to open the national labs more to industry and encourage greater collaboration.

PART 2: FINDINGS FROM TLSI DIALOGUE 5

Department of Energy: The Path Forward

Dr. Steven Koonin
Under Secretary of Science
United States Department of Energy

I want to talk about the Quadrennial Technology Review (QTR) that we've been executing within the Department of Energy (DOE) for the last six months. The basic goal is to write down, understand and encourage a dialogue on what exactly the Department "does" in energy. The process has three objectives. One is to create and promulgate a simple framework for energy that non-experts can use to think about it, talk about it and make decisions. The second is to elucidate the roles that the Department, the national labs, the private sector and academia have in changing the energy system in response to national goals. The third is to write down principles and priorities that should guide the Department's work. This effort also informs DOE's ongoing and annual budget process that operates in parallel.

The QTR is meant to have a longer time horizon, analogous to the quadrennial defense review or the quadrennial defense and development review. We seek to give greater coherence to the Department's thinking and planning as it carries out various energy technology programs. The process actually kicked off in November 2010 as the result of a report of the President's Council of Advisors on Science and Technology (PCAST) overseen by Ernie Mooners and Maxine Savage, which itself followed on a 1997 energy R&D report that John Holdren chaired when he was a PCAST member. Both reports said that the DOE should take a serious look at its R&D programs. I've been working on QTR with a team since January 2011.

Steven Koonin, U.S. Department of Energy; Ray Johnson, Lockheed Martin Corporation; Deborah L. Wince-Smith, Council on Competitiveness; and Chad Evans, Council on Competitiveness.

The process has necessarily been public. We issued a public training document in March for comments, and we ran five discipline-specific or sector-specific workshops on vehicles, fuels, the grid, electricity and use efficiency. Just yesterday, we had about 300 people in a capstone workshop talking more broadly about the principles and roles that should guide the Department. Somewhat surprisingly, this kind of exercise has not been executed in living memory, and it's been very interesting to ask people, "What do you think the Department does do?"

I want to talk first about the transport energy sector, then stationary and then more generally. On the transport side, we realize that the oil issue has several dimensions. There is the balance of payments issue—the billion dollars a day imported. There is the geopolitical issue of the concentration of easy oil reserves in a few countries and the sway of the Organization of Petroleum Exporting Countries

(OPEC) on the market. There is the greenhouse gas issue and the price at the pump issue—including price volatility. And then there's the jobs issue, in that we could easily create more jobs by ramping up domestic production.

Ideally you'd like a strategy that deals with them all, but they are different. One insight is that increased domestic production or increased bio fuels will not fix the price problem. There is a great anecdote back in about 2000. There was a strike by the UK lorry drivers because of rising diesel prices. At that time, the UK was oil independent, but nevertheless the prices were going up. That shows we're going to sell oil at whatever the global price is, and we do not have control over the global price. We can't produce fast enough to really affect the global market with demand going up at a million barrels a day and OPEC being the swing producer.

There are three strategies we need to pursue. One is vehicle efficiency. Currently the debate is about standards. My sense is that we can build cars that are 30 to 40 percent more efficient for roughly $1,500 more per car, maybe less. Industry and the Environmental Protection Agency are debating about how cheap efficiency is, but it's in that range.

The second thing we need to do is migrate to non-hydrocarbon fuels if we want to de-couple from the oil market. There are not many choices. You've got electricity, natural gas and hydrogen—that's it. When you consider the need to co-evolve the fueling infrastructure, electricity looks pretty good because you can use existing infrastructure to serve ordinary internal combustion engines, hybrids, plug-in hybrids and full battery vehicles. You can charge a Volt now on 110-volt outlet, although it may take you a little longer than you'd like.

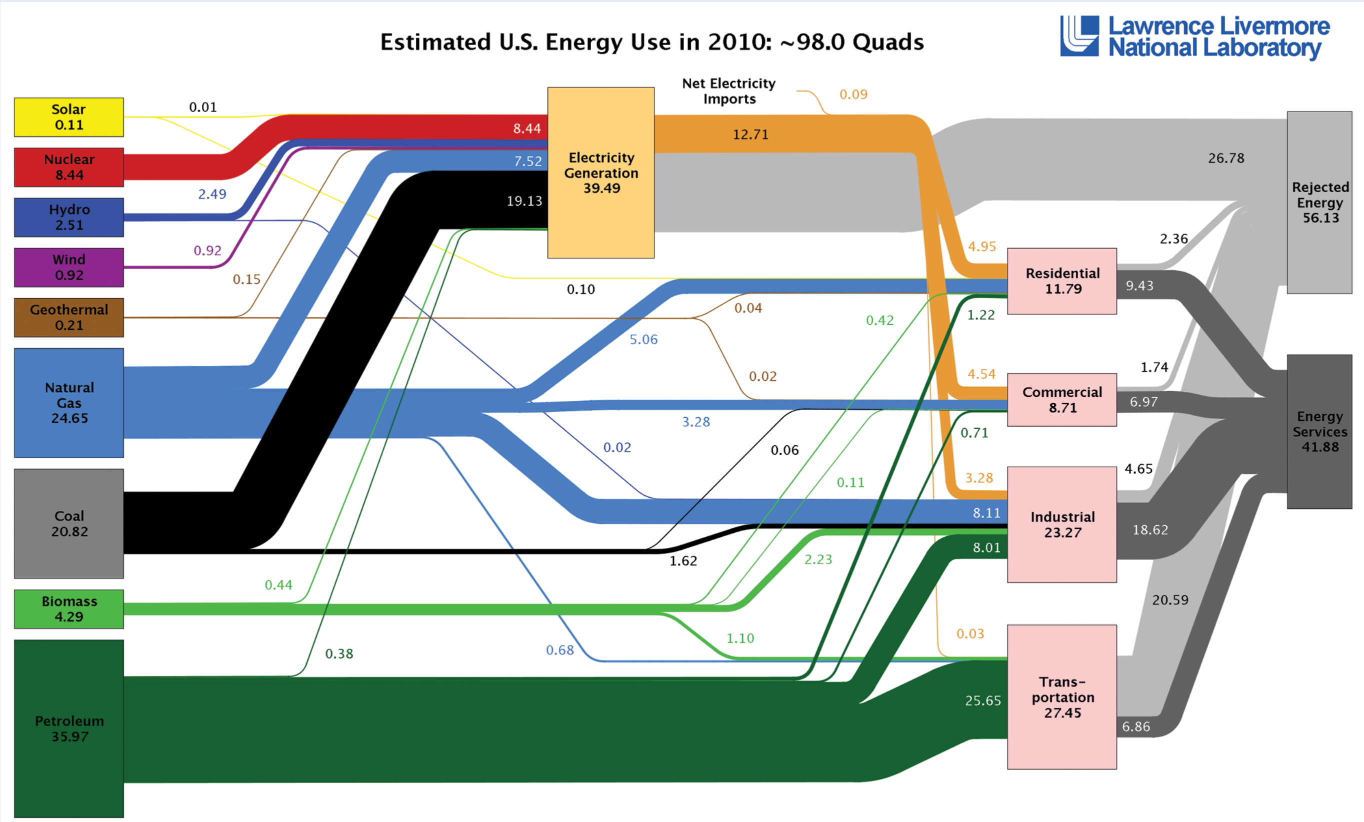
On the other hand, if you look at natural gas or hydrogen—at least for the light duty vehicle fleet—there are infrastructure issues that loom large in our thinking. We also recognize that the heavy-duty fleet is different from the light duty fleet. We're not going to obviate the need for liquid hydrocarbons in the heavy-duty fleet. There are great efficiency possibilities, but also a need for advanced bio fuels. We therefore are probably more interested in diesel rather than gasoline, and ethanol rather than bio fuels.

The Department has struggled to tell the clean electricity story. We spend about half of the Department's energy R&D dollars on clean electricity generation, the biggest share of that being fission. The next biggest chunks are biomass and carbon capture and storage, a somewhat smaller chunk in solar, and then lots of little things: geothermal, wind, hydro, kinetic and so on. What is the rationale for clean electricity beyond greenhouse gases? What principles might be used to choose among the technologies for federal support as opposed to private sector support?

The grid has emerged as great opportunity, a chaotic landscape that presents many potential ways to do better. If you look at the famous Livermore energy flow diagram (Figure 1), we don't have enough data on end use in residences and industrial processes in order to drive efficiency more effectively. We don't have enough data.

Some higher level insights came out of the discussion yesterday on the principles and roles that should guide the Department. There is a great desire for decisions and greater clarity from the Department, i.e. tell us what you really do and don't give us a disconnected set of vignettes, but rather an integrated piece. There was a lot of discussion yesterday about balance across the portfolio, but one man's

Figure 1.



Source: LLNL 2011. Data is based on DOE/EIA-0384(2010), October 2011. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports flows for hydro, wind, solar and geothermal in BTU-equivalent values by assuming a typical fossil fuel plant "heat rate." (see EIA report for explanation of change to geothermal in 2010). The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 80% for the residential, commercial and industrial sectors, and as 25% for the transportation sector. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

balance is another man's bias. Having that difficult conversation about how much should we do in fission; how much we do in solar; where is the optimal leverage; has been interesting and is still somewhat unresolved.

For example, we have been looking hard at cost issues in the hydrogen program. The program examined the cost in cents per mile driven for fuel and vehicle, and so on projected out to 2030. The costs for a hydrogen vehicle were projected against the cost for other alternatives, conventional, plug-in hybrid, battery vehicle and natural gas. The assumptions that were used for hydrogen were very optimistic. The assumptions used for other technologies, however, were today's technologies not taking into account any evolution. There is a need for an integrated view that we have not been able to pull together—both about transport and the stationary sector.

On the positive side, our discussions made very clear the importance of roles beyond R&D for the Department. To quote the press releases, the Department often talks about itself as inventing the breakthroughs that will win the clean energy future. It is important that we do that, but some of the most effective things we do are providing information to people in industry, consumers and regulators about what technologies might work and what results were gleaned from efforts in the past.

The Department also has a convening and agenda setting role. We alone can convene the whole grid community—the technologists, utilities, regulators and operators. We also set agendas. If the government prioritizes batteries, people will mobilize in that direction, or bio fuels or hydrogen or solar. We have that power. It needs to be synergistic with the R&D we support, and we haven't used it very strategically in the past.

Another insight is that we need to understand much better, and be closer to, the private sector. The Congress awards us four billion dollars on energy R&D. We'd like it to be larger, but even if it were two or three times as large, it would still be small compared to what the private sector is spending globally, and energy markets are globally integrated. So we need to use our resources to catalyze what the private sector does. To do that effectively, the Department must understand better how the private sector thinks. We haven't got an awful lot of that knowledge in the Department. We are working to do better, but we need more data.

Finally, what came through yesterday were systems, systems, systems. We at the Department tend to be technologists. To be really effective, we need to understand the system—physical, economic, regulatory—in which the technology will be deployed. These are all things that will get embodied in the QTR that is 80 percent written at this point. We have been diligent to keep the White House in the loop as we've gone through this six or seven month process. Hopefully we'll release the report before the end of the year.

Discussion

Participants raised questions about how the DOE planned to help bridge the gap in capital between R&D and commercialization. One participant noted that at least two gaps (valleys of death) exist for new technologies—one at the invention stage and another at the large-scale deployment phase. Koonin was asked about the success and future of the Department's loan guarantee program, and whether the program would be able to take on projects risky enough to be transformational.

Koonin stated that DOE is doing a good job of encouraging the deployment of new technologies, but he acknowledged the limitations of government. "At some point, all of these have to take off on their own," he said, also emphasizing that the proper role of government is not to compete with the private sector. Koonin noted that government might have its greatest impact by helping speed energy technologies to market through standards and R&D. He offered as examples the role of research and standards to facilitate the safe extraction of shale gas and develop carbon capture technologies.

Participants then commented on issues related to China, asserting that the Chinese are advancing innovations more aggressively and with lower regulatory and capital hurdles. Attendees also observed that China continues to invest heavily in university infrastructure and is gaining an advantage through its sheer number of science and engineering graduates.

Koonin responded that although the United States has lost ground on commodity manufacturing, it continues to lead in several high-end, high-value manufacturing sectors. He also stated that America retains an innovation lead in clean energy and other technologies, but that the nation lags in the deployment of such energy technologies. "I don't see how we're going to lead in deployment when we put in at best 15 gigawatts a year of capacity in this country for electricity, whereas China puts in 70 or 80 gigawatts a year," he explained.

Pradeep Khosla, dean of the College of Engineering at Carnegie Mellon University, kicked off a conversation about how the national laboratories might privatize a greater share of their intellectual property. Steve Ashby, deputy director for science and technology at the Pacific Northwest National Laboratory, shared that the TLSI Accelerating Innovation Working Group was looking at incentives related to this issue. "What are the incentives given by the Department to the contractors who operate the laboratories?" he asked rhetorically. "A lot of times, it is around generating the IP, but not necessarily working to commercialize and deploy the IP."

Steve Rottler, chief technology officer and vice president for Science Technology and Research Foundations for the Sandia National Laboratories, noted that in addition to incentives, a key challenge is that many of the technologies developed by the labs are very novel. "They're extremely innovative and have all sorts of possibilities, but most of the things that we do are not ready for commercialization," he said. Such technologies require significant additional investment to develop them into something useful to the private sector. "That's the biggest gap that I see," Rottler relayed. Ashby echoed that point, noting that the labs seldom have adequate funding to support such development. "That's beyond what we typically do well, so I think we have to decide what role the labs should play."

Koonin weighed in that the labs are probably most effective at commercialization not when engaged in more transient tech transfer efforts, but instead when in sustained collaborative partnerships with industry.

Participants noted that universities face similar challenges. One suggestion was that universities (or labs) should offer a non-exclusive commercial rights royalty suite to companies. If licenses were less burdensome, it was suggested, money from companies and venture firms would be invested. Other speakers noted that a balance would need to be drawn between fostering trusted industry partnerships and ensuring that taxpayer funded investments did not unfairly favor a single or small group of companies. An idea emerged that perhaps a competitive process could be established to ensure fairness, but also offer a level of exclusivity that would incentivize companies to participate and create a reasonable chance to generate a profit on their investment.

Steve Rottler, Sandia National Laboratories; Wolf von Maltzahn, Rensselaer Polytechnic Institute; Monty Alger, Air Products and Chemicals, Inc.

Tom Halbouty, vice president, chief information officer and chief technology officer of Pioneer Natural Resources Company, raised the issue of national oil companies in China and India backed by sovereign funds. The funds, he said, enable the national companies to compete on a scale 10 to 20 times larger than a private company like Exxon Mobile and on an ability to lock up traditional hydrocarbon reserves. This ability to guarantee up to 40-year pricing models for energy attracts advanced polymer industries to their countries to the detriment of U.S. competitiveness, Halbouty asserted.

PART 2: FINDINGS FROM TLSI DIALOGUE 5

Setting the Stage

Johnson thanked Koonin and offered a few framing remarks for the Dialogue. He noted that the TLSI has expanded participants' knowledge of the role of technology in competitiveness, but that technology alone will not be enough to meet the nation's challenges. Johnson suggested that the U.S. is struggling to define the role of government in dealing with the global political-economic environment, in reforming policies and in leveraging U.S. capabilities.

Global political-economic environment: Johnson noted that the American two-party system, despite many attributes, struggles to address problems like the nation's debt or make big bets in a timely manner. At least in the short term, he observed, China has been effective at building world class universities, research establishments and infrastructure that are closing the competitiveness gap with the United States.

Policies: Johnson explained that American tax and regulatory policy, and the uncertainty of how it might change, has stranded trillions of dollar from being invested in new U.S. ventures. "Part of solving this second valley of death is creating a regulatory and policy environment that makes it attractive for [money] sitting on the sidelines to make those big bets," he said.

Capability: Johnson expressed concern that America's innovation advantage is eroding, and that too many analysts underestimate the creativity capacity being developed overseas. "They are good inventors, and they're getting better at innovation. The numbers game is going to make it even harder for us to keep up when you consider just one of the components—Science, Technology, Engineering and Mathematics (STEM) graduates."

Ray Johnson, Lockheed Martin Corporation, and Deborah Wince-Smith, Council on Competitiveness.

He continued, "As we think about the TLSI, it's important for us to take a systems view…we have a wonderful platform with the people who are represented on the TLSI and within the Council to inform the government on these policies and other issues." Johnson encouraged participants to consider the role of government in high risk R&D, creating a more attractive investment environment and taking bold steps that make the nation more prosperous and secure. He contrasted the outlook in America today with past efforts like the space program and construction of the interstate highway system. "We ought to be thinking about recommendations that have both national security and commercial benefits."

One of the TLSI goals is to identify technology and policy road maps to sustain the technology advantage required for U.S. security and economic competitiveness, Johnson reminded. "We have made excellent progress in those areas. I'd like to advance our thoughts in two primary areas relating to the technology road maps. First is helping the nation improve its decision making process across the agencies and across missions. We circulated a pre-report last week that talks about what the United States might do more effectively. Second, are there key technologies that are not being adequately pursued?"

Johnson introduced the speakers to lead that conversation: Rottler and Bart Gordon, former chairman of the House Science and Technology Committee, partner at K&L Gates and a distinguished fellow with the Council.

Deborah Wince-Smith and Chad Evans, Council on Competitiveness, Bart Gordon, K&L Gates and Council on Competitiveness.

How Can the United States Improve Decision Making Across the Innovation Enterprise?

Gordon stated that the federal decision-making process for research is fairly rational, if complex, and noted the interplay between and across agencies as well as between the executive and legislative branches of government. "The backbone of that is really a lot of very bright, able, professional staff," he said.

Gordon observed that Americans have been successful innovators because significant resources have been devoted to research and lab infrastructure. "If you throw enough up against a wall, something will stick," he quipped. "But in today's situation with much more competition, with diminishing resources, clearly we have to be more focused."

PCAST is having the same conversation, shared Gordon. The president charged PCAST with recommending how the U.S. R&D enterprise should be configured. A PCAST subgroup held a roundtable in 2011 in which Gordon participated. The interest in the topic was high enough, he said, that the entire PCAST now wants to be involved. Gordon also offered to propose ideas generated by the TLSI process at the PCAST deliberations.

Rottler opened by offering a national lab perspective on innovation. "I'm optimistic about innovation in the United States because of what I'm exposed to every day," he explained. He noted that the labs are still able to hire some of the most talented people in the world, driven to develop new knowledge and invent new things that can be deployed for the public good. The second reason Rottler remains optimistic is that generally, the government has been supportive of the investments necessary for innovation to flourish. He acknowledged the short-term struggle each year for appropriations and the occasional dips and plateaus in funding, "but if you look over a long period of time, and for me that stands now at nearly 27 years, I think actually it's working quite well from the perspective of government investment."

Another cause for optimism, Rottler stated, is an evolving ecosystem emphasizing partnerships and increasing collaboration. "Not just between labs," he said, "but between labs and universities, between labs and government, between labs and the private sector and all combinations in between." Rottler described such partnerships as an essential ingredient for innovation. "Some of the greatest work that I see is where you bring together individuals from multiple disciplines who traditionally have not worked together for the sole purpose of exploring the art of the possible at the boundaries between different disciplines and different technological approaches."

Despite his optimistic outlook, Rottler listed two challenges on the horizon. One is that the system of federal support for innovation programs is decentralized beyond what he consider optimal. Because the federal system is very program and task focused, the innovation process gets fragmented, he explained. "That works against characteristics that you need to foster innovation." The the same trend is evident on Capitol Hill, he observed, "Where everybody has their jurisdiction; everybody has their programs and manage in that sphere."

Rottler closed by noting a second challenge. "The government's role in fostering innovation is critically important, but that's not widely recognized within the policy community, and certainly not widely enough within the public." He expressed concern that this lack of appreciation in difficult budget times could undermine the key role these programs play in the country's economic security.

Discussion

Johnson opened the conversation by complimenting the historic achievements of the U.S. university research system and the federal laboratories overseen by the Departments of Energy and Defense. He supported suggestions, however, that lab charters be reviewed to ensure that they are broad enough to solve national priorities and flexible enough to encourage outside partnerships.

Mel Bernstein, senior vice provost for research and graduate education at Northeastern University, shared an insight from a recent roundtable discussion of university research officers. "All of us are rethinking technology transfer," he said. "Our experience in technology transfer over 20 years has not been cost effective." Bernstein acknowledged success stories, but characterized them as the exception. He suggested that universities are reconsidering their role in the larger innovation ecosystem.

Northeastern has a robust co-op program where students spend time with industry. Bernstein observed that students bring that experience back into the institution, enabling Northeastern to foster creativity and perform a greater share of work that is relevant to the innovation process. "In many regards, that could be a more valuable role in the innovation pipeline," he suggested, contributing talent and generating ideas that are more closely tied to commercial challenges.

Bernstein believes that the university community is moving toward greater engagement with industry in order to inspire and prepare students. He also predicted that although institutions still hope to earn money from their discoveries, a growing number will place more emphasis on getting ideas to market and reshaping the terms and ways that can happen. "I hope a market place for ideas comes out of a variety of institutions where those institutions are not capable of developing the ideas themselves—perhaps an e-Bay model for these kinds of activities."

Ashby returned the conversation to the national laboratories, agreeing that the labs are successful when they partner across disciplines and institutions. He expressed concern that funding is stove piped around disciplines, technologies, or missions in ways that may limit a lab's potential to achieve outcomes for the country. "The question is how well we're directed and harnessed," he stated. "We have the capability to contribute across a variety of areas."

Ashby also is concerned that an erosion of stability in R&D funding could hinder the labs' ability to

Jim Phillips, NanoMech.

attract top talent. "If we want to compete for talent, people need to know they're going to have the ability to work on some of these most challenging problems and have that stability."

Jim Phillips, chairman and CEO of NanoMech, asserted that America's largest innovation challenge is not generating more ideas from universities and labs, but rather producing the entrepreneurs and capital to take ideas to market. "We have so much stranded invention compared to other countries, it's unbelievable," Phillips said. "I walked through Oak Ridge National Labs and saw at least 50 ideas that are phenomenal, things like super hydrophobics that have huge potential markets. But where are you going to get the capital? The bad economy has taken the risk takers off the table. The shortage of angel capital is worse now than in the last 20, 30 years."

Phillips also emphasized the importance of improving the speed and reducing the cost of patenting ideas. "How do you fund intellectual property protection if you're a small guy today? It's so expensive and can take four to five years. In the meantime, the Chinese read about it and develop a product based on what you're trying to patent, and they bring it to market. And it's not just China—we're up against state run companies that fund those projects we aren't funding."

Halbouty built on Phillips' comments, sharing a saying that invention is the conversion of cash into ideas and innovation is the conversion of ideas into cash. "Over the last 10 or 12 years, the United States has disassembled some of its incentive systems," he said. Halbouty noted that although the Sarbanes-Oxley law fixed some important problems, it also restricted the ability of some firms to go public and has reduced the availability of startup cash. "China, India, Singapore, Israel—they shop our chambers of commerce," Halbouty asserted. "They bring capital to take businesses to their shores. If it takes us three or four years to get something done, somebody else is going to strike while the opportunity stands. Getting our liquidity and our financial markets up again is really important."

Ajay Malshe, the founder, executive vice president and chief technology officer of NanoMech, kicked off a discussion about engineering by suggesting that the United States establish a National Engineering Foundation. "Today's university system is an incredible environment for creating disruptive innovation, but there is an ecosystem missing in this country for evolutionary innovation, which is engineering. Engineering converts ideas and innovation into cash, and we don't produce enough engineers."

Monty Alger, vice president and chief technology officer of Air Products and Chemicals, agreed with Malshe and expressed concern that the United States also may lack enough entrepreneurs who act as a critical interface across the discovery, development and commercialization process.

Andrew Garman, a founder and managing partner of New Venture Partners, perceives a lack of engineers in public and private sector leadership roles. "There are 535 members of Congress, and only six of those are engineers or scientists," he relayed. In the private sector, he noted that virtually all technology companies begin with an engineer as a founder, "but they ultimately are led by sales or finance people." Garman suggested that engineering schools rethink curriculums that are purely technical to encourage greater engineering leaders. Halbouty advocated adding some type of communication course, "because if you can't sell and summarize your ideas, you become incapable of moving the ball forward." Ashby agreed and also suggested project management instruction.

Khosla shared that Carnegie Mellon University has begun to look at a next generation undergrad curriculum designed to encourage innovation across disciplines. The challenge, he said, is that it is difficult to change engineering courses too much "because four years is about the limit. The cost of education is so high that nobody wants to pay for a fifth year. The amount of knowledge is expanding exponentially so one has to choose what subjects to master in depth." Khosla believes that the solution may be to reform general education requirements rather than the engineering curriculum. He acknowledged, however, that reforming general education requirements can be very challenging, particularly at public schools where faculty protect their subjects.

Bernstein articulated another challenge in curriculum reform. "The problem we often find is that industry comes to us and says we need a new kind of engineer. They might say, for example, we want a manufacturing engineer. So we create a manufacturing curriculum." By the time schools graduate students from those programs, Bernstein said, companies often have new needs such as mechanical or chemical engineers.

David Lifka, director of the Center for Advanced Computing at Cornell University, added that engineering is becoming more highly specialized, with several areas within nanotechnology alone. He also emphasized the importance of internships and co-ops. "That's the way you can get students who are highly focused, highly intelligent and highly specialized and teach them how they need to behave when they get into a professional environment." Lifka encouraged firms and labs to contribute to engineering's future through such channels.

Gordon reminded the group that science and engineering awareness begins in K-12 education. He recalled a statistic that 59 percent of middle school math teachers in the United States do not have a certification to teach math. "So when Congress re-authorized the National Science Foundation (NSF), the legislation created a scholarship program for math and science students who would agree to teach for five years upon graduation." Gordon added that the NSF is not large enough to fully address the problem, so supporters in Congress are working to establish a similar program through the Department of Education. He encouraged TLSI participants to engage the debate on overlapping STEM education programs to ensure a positive outcome and to serve as role models by visiting high schools and middle schools.

Johnson underscored the importance of tapping into underrepresented populations for engineering and welcomed the dialogue participants to become involved in two 2012 efforts: the USA Science and Engineering Festival and a National Engineering Forum to be held with the National Academy of Engineering.

Dan Hitchcock, associate director for advanced scientific computing research at the DOE, shared his observations on the types of skills needed in an engineer to commercialize innovation. The DOE Office of Science is often involved in tech transfer issues, he stated, because of federal programs that give industry access to the department's high performance computers. "We made the decision a couple of years ago that the intellectual property created in our program would be released under open source licenses," Hitchcock said. To take advantage of this knowledge and capability, he stated, "You need either engineers who have business skills or finance people who have engineering skills so they can talk to a chief financial officer and explain an idea that will pay off and the data that supports that conclusion. These people are hard to find, and they become the entrepreneurs."

Wince-Smith shifted the conversation, emphasizing the role regulations and standards play in the innovation and commercialization process. She asserted that such issues should be pursued as aggressively as research and STEM talent. "If you look at the regulatory burden on this economy, it is staggering and getting worse. We have 28 more major regulations this year than last year, and there is no place in our government that does an assessment of the total cost of regulations across sectors." Wince-Smith noted that data from 2004 suggests that the regulatory compliance cost to U.S. business was two and a half times the value of America's national expenditure on R&D, both public and private.

Wince-Smith cited other concerns, such as China and India not yet being bound by the World Trade Organization (WTO) Government Procurement Agreement. "They don't have to follow global disciplines like the United States and Europe, so they can procure for huge infrastructure projects in ways that discriminate against foreign competitors." She also raised antitrust decisions made on 20th century terms "between Michigan and Ohio, not Michigan against Sichuan Province." Finally, Wince-Smith noted the importance of industrial standards as a competitive tool that is underutilized by the United States. She challenged the TLSI's academic members to supply estimated cumulative cost data and lost opportunity insights due to regulations and standards. "That would be an incredible piece of new knowledge that would have a major impact on achieving our goals," she said.

Rottler noted the important role played by state and local governments, sharing how New Mexico's state legislature is working with Los Alamos and Sandia labs, supplying a tax credit against gross receipts that labs can use to offer small firms access to the lab facilities. The state has maintained that support even in a tough budget climate.

Rick Shangraw, senior vice president for Knowledge Enterprise Development and the director of the Global Institute of Sustainability at Arizona State University, expressed concern that pilots and demonstrations across federal agencies lack coordination. He noted some attempts by the Defense and Energy departments to work together on energy pilots, but suggested that higher levels of coordination and consolidation of funds across agencies would enable more to be achieved for the same dollar.

Jim Davis, vice provost for information technology and chief academic technology officer for the University of California, Los Angeles, raised the linkage between manufacturing and innovation. Davis stated that research and tech transfer are the front end of the production pipeline, but that a broader ecosystem is required to move ideas into mass production in the United States. "What does the ecosystem look like?" he asked. "How do you bring pre-competitive and competitive spaces together? How do you truly lower the cost of infrastructure and deployment of technologies in real manufacturing settings?" Davis urged participants to take these considerations into account.

PART 2: FINDINGS FROM TLSI DIALOGUE 5

Working Group Updates

Chad Evans, senior vice president at the Council, introduced the three TLSI working group chairs in attendance—Ashby, Khosla and Bernstein. Hank Foley, the vice president for research at Pennsylvania State University and chair of the Innovation Outreach Working Group, was unable to attend. The Outreach Group will develop a strategy to take TLSI ideas forward in 2012, Evans said, including to state and local leaders as suggested by Rottler.

Ashby, who chairs the Accelerating Innovation Working Group, noted that his group has put forward five broad objectives. "We then came up with three to five recommendations per objective that we feel would be actionable," he explained. Ashby highlighted a few recommendations from each objective.

The first objective is to define shared outcomes that motivate and coalesce teams. "We're trying to bring together teams to work across institutional and disciplinary boundaries," Ashby said. "One of the ways to do that is to focus on a shared outcome that requires skills to come together." The recommendations include: structuring government-sponsored competitions that encourage partnerships to achieve clearly articulated outcomes and devoting a greater share of federal research dollars to basic research that is informed by a market pull or public need.

A second objective, Ashby said, is to build communities of commercialization and entrepreneurism. Recommendations include making information more easily available about research projects at federal laboratories and universities, and coordinating federal funding to innovation hubs that center on a particular set of challenges. Ashby acknowledged work already underway on innovation hubs and shared the group's belief that the hub location should be contingent on funding and policy support by state and local governments.

Steve Ashby, Pacific Northwest National Laboratory, and Thomas Halbouty, Pioneer Natural Resources Company.

The group's third objective is to facilitate greater sharing of intellectual capital. Ideas include easing the restrictions on how labs and universities share IP across partnering organizations and enabling the bundling of IP generated by consortia. "Can we simplify this process and establish incentives or requirements at labs and universities that adopt IP policies that promote industrial engagement and commercialization?" he asked.

The fourth objective is to create an innovation friendly policy environment. Ashby noted that he has coordinated with the Regulation and Policy Working Group to minimize overlap. Recommendations include making the R&D tax credit permanent and establishing innovation metrics across U.S. science and statistical agencies that are more outcome-based. Another idea was to extend visas for commercialization-focused research to retain more talent.

The final objective, Ashby said, is to bridge gaps in the innovation pipeline. "We've talked about the two valleys of death," he observed. "One idea is to establish regional forums that bring together government officials, chambers of commerce, angel investors, venture firms and research institutions. We encourage that to happen on a more regular basis." The working group also supports the creation of technology maturation funding road maps across agencies similar to the DOE's QTR.

Khosla, who chairs the Regulation and Policy Working Group, reported next. He explained that the group drew from a 2008 PCAST report urging reform of policies that deter industry-supported research on university campuses. The working group selected four priorities. The first is to revise International Trade in Arms Regulations (ITAR). Khosla asserted that the ITAR regime overly restricts foreign students studying in the United States from researching technologies that do not pose security threats. Khosla also stressed that the control lists require updating so that widely available technologies are not subject to export restrictions.

The second goal is to retain highly skilled immigrants educated in the United States. "More than 50 percent of the Ph.D. population in the country is foreign born, like me," Khosla said, "and more than 50 percent of the businesses created in Silicon Valley were by foreign born citizens of this country. We used to stay forever, but in the last seven or eight years, China and India are becoming more attractive to go back to. There's more money than before, better quality of life, family." The United States must reform its immigration policies to hold on to this talent, he emphasized.

The working group's third priority is to streamline and modernize IP and patent processes. Khosla complimented the progress and steps outlined dur-

Pradeep Khosla, Carnegie Mellon University; Spiros Dimolitsas, Georgetown University; and David Lifka, Cornell University.

ing TLSI Dialogue 3 by David Kappos, the Under Secretary of Commerce for Intellectual Property and the director of the U.S. Patent and Trademark Office. He also expressed hope that Congress would enact patent reform legislation that would reduce costs and delays in the system.

The last issue Khosla reviewed was removing conflicts in regulations that impact the research enterprise. "This is a really big issue," he stressed. As an example, Khosla noted federal tax rules governing tax free bond financing, which is how most universities raise money to construct buildings. The rules set conditions for universities to accept funding from the private sector to support research in those buildings. The rules also limit pre-negotiations on IP rights for university-industry collaboration in such facilities. The tax rules run counter to certain conditions set by research agencies that require or encourage collaboration with industry in order to receive funds.

Bernstein, chair of the Talent Working Group, opened his summary by acknowledging the importance of STEM talent and explaining why the working group chose to focus elsewhere. "If we were able to audit the efforts going on to support STEM in this country,


Mel Bernstein, Northeastern University.

it would be staggering." He described not only government STEM efforts, but also those by companies, labs, universities and foundations. "We decided to focus on other areas where a talented work force is needed for innovation and competitiveness, including people earning degrees from community colleges and mature workers," he said.

Bernstein asserted that many community colleges have established innovative curriculums to prepare people for not only a four-year or associates degree, but also to teach skills needed in the local work force. Discussions within the Council's U.S. Manufacturing Competitiveness Initiative (USMCI), he said, also identified community colleges as an important focal point for talent. "We plan to engage community college leaders and consider best practices that could be developed into national guidelines."

The working group also discussed America's growing pool of mature workers and ways they could contribute to the nation's talent needs, Bernstein said. "One example comes from the Council's high performance computing (HPC) discussions I attended at Lawrence Livermore several months ago. Could mature workers offer capabilities for simulation and visualization that is needed in order for small to medium-sized companies to use HPC? This might be an important opportunity for programs and training efforts that enable people to work. It's a little bit like what happened several years ago when computer-aided manufacturing techniques were developed. One of the barriers was who would supply the skills."

"The working group's focus is how to facilitate both of these groups contributing to innovation and becoming part of this emerging new community of workers in a new manufacturing model. We also think there are lessons to be drawn from what universities have been doing with internships and co-ops. Many students are now required to be exposed to real world problems, to understand them and to benefit from that experience." Bernstein added that the working group believes that there are opportunities to establish incentives that link older workers with younger workers in business environments.

Discussion

Amy Kaslow, a senior fellow with the Council, complimented Bernstein and stressed the importance of an inter-generational approach toward cultivating talent. "The idea is to take these two seemingly competing work forces, new entrants and mature workers, and turn them into complimentary forces," she said. Kaslow noted that there are several outstanding programs across the country, such as mature workers with experience in STEM fields training teachers and working with students, including students in or considering community colleges. The Council is looking for ways to scale successful programs nationwide.

Kaslow shared a few statistics about the mature work force. Between 2008 and 2018, she said, 80 percent of the increase in the labor market will be generated by mature talent. "That is due to demographics, longer life spans and people extending their working lives. If you are 60 years old today,

Amy Kaslow and Cynthia McIntyre, Council on Competitiveness.

you have a better than 50 percent chance of living until you're 90. There is an enormous need for the mature work force to transfer their knowledge and to cultivate and to train new entrants." She also shared a finding from a Kaufman Foundation study that workers 55 years and older are responsible for the greatest number and most successful technology startups. Those workers have stronger networks, experience and more access to capital.

Tomás Díaz de la Rubia, deputy director for science and technology at the Lawrence Livermore National Laboratory, admitted that many scientists are "actually not very good at communicating to kids the excitement of science." He described a program at Lawrence Livermore called Science on Saturday. At first, said Díaz de la Rubia, scientists would talk to kids who came on Saturdays, and it was moderately successful. "Then someone had the idea to connect with teachers, so lab scientists and teachers lecture together. Last year, we had 6,000 kids come and had to do them multiple times every Saturday. We put them on Internet TV through the University of California, where they've had 2.8 million viewings. I think it is generating tremendous interest in the schools and that connection with the teachers can change the culture."

Díaz de la Rubia noted that the program operates in a diverse community in the San Joaquin Valley. "If we want to take advantage of the diversity that is a hallmark of our country, we have to get better at providing role models and mentors," he said.

Halbouty agreed on the importance of role models and raised an issue of how engineers need more viable workplaces. "Many U.S. companies treat engineers the way construction workers are treated—there's a large project to deliver, they staff up, bring engineers on board, execute the project, and they're gone. If engineers find that they are hired and let go with the ebbs and flows, and they don't see their accountant or lawyer friends going through the same experience, those experiences get back to younger kids. I'm a firm believer that you not only have to mentor kids when they're young, you also have to bring them into vibrant challenging workplaces."

Phillips complimented the working groups for their coverage of the key issues. "I hope we make those things a reality," he emphasized. Phillips noted the robotics competitions organized by Dean Kamen as one of America's most successful STEM programs. "It just shows how good STEM programs can be if you make them fun and competitive." Phillips also noted that all of the scientists in his company are foreign born, underscoring the critical role of improving America's immigration and visa rules. "We're pushing these people out," he exclaimed. "We really are. If there's one thing that could be fixed and prioritized that would have an immediate impact on technology development and our future as a country, it's that." Phillips expressed that he and other TLSI colleagues would be willing to testify before Congress to push forward on this issue.

PART 2: FINDINGS FROM TLSI DIALOGUE 5

High Performance Computing

Evans announced that the Council has re-launched the HPC initiative under the leadership of Díaz de la Rubia; Michael McQuade, the senior vice president for science and technology at United Technologies; and Bob Buhrman, the senior vice provost for research at Cornell University. “We are elevating the HPC initiative,” Evans said, “which the Council helped launch in 2006 to emphasize a technological capability that is a competitive differentiator.”

Evans introduced the discussion leaders: Díaz del la Rubia; Dan Hitchcock, associate director of advanced scientific computing research at the DOE; and Cynthia McIntyre, senior vice president at the Council.

Díaz de la Rubia explained that HPC modeling and simulation confer competitive advantage not only in research and development, but also by speeding up the innovation cycle. The HPC initiative aims to stimulate and facilitate the wider usage of HPC across the private sector to drive productivity. “As the Council has said many times, to out compute is to out compete. That captures the essence,” he said. Díaz de la Rubia reviewed the goals of the initiative, such as explaining to public and private sector leaders how HPC can act as a technological foundation for competitiveness and security. Other goals include policy recommendations to maximize HPC impact and to lower barriers to HPC usage. HPC modeling and simulation technologies “allow firms of all sizes to innovate more quickly and reduce costs at every stage of the product life cycle, from discovery to commercialization,” he emphasized.

The United States has invested in HPC for five to six decades, Díaz de la Rubia reminded TLSI participants, which no other country has done, regardless of the hardware they acquire. “We have an edge and have to take advantage of it today, because we are in danger of losing this competitive advantage,” he warned. Díaz de la Rubia shared an observation from a recent trip to China. “It is one thing to have a big piece of iron and steel with silicon inside, and another thing to do something useful with it. I have to tell you —I found the pace of development and increasing capability there to be absolutely staggering.”

Andrew Garman, New Venture Partners, and Tomás Díaz de la Rubia, Lawrence Livermore National Laboratory.

Every Chinese supercomputing center, Díaz de la Rubia said, was brand new and populated by a workforce with an average age of about 30 to 32 years old. “Interestingly, their focus is on innovation in the private sector. They are using these machines to develop indigenous technologies in key industrial sectors like aerospace, energy, materials, biotechnology and health care—and they’re doing it with investment that brings together state enterprises, private companies and government around these capabilities. That is not happening in the United States,” he asserted. In America, Díaz de la Rubia stated, HPC is making tremendous progress on energy, national security and basic science applications, but not across the entire innovation sector. He noted exceptional work done by a handful of major U.S. companies, but described adoption across all U.S. companies as slow. "It is not happening slowly in China," he stressed, "and it's a call to action for us."

Díaz de la Rubia expressed frustration with federal policies that make it "extraordinarily difficult" for national laboratories to use federal land to create private-public innovation centers that would be co-funded by both partners and apply technologies like HPC to industrial challenges. A notable exception is a DOE program that enables partnerships on clean energy technologies. "I think that a program of that nature could expand into other industrial areas like manufacturing and go a long way to help the private sector adopt HPC." Little expressed concern with this restriction and suggested that the TLSI consider action to remedy the problem.

Díaz de la Rubia closed his prepared remarks by urging participants to also think about leading edge technology like exascale computing, which would be a thousand times more powerful than what is available today. He noted that the capability of large supercomputers when he was in graduate school is available now in an iPhone. "Exascale computing will be in the electronic devices we use 10-20 years from now, but to get there we will need a long-term funding commitment by the public and the private sector." The exascale challenge, he explained, is not linear. It will require technical innovation in hardware and software that is "completely different from anything that we're doing today." The HPC initiative also should advocate that America invest in the leading edge, he stated.

Responding to a question by Jim Phillips about how HPC intersects with cloud computing, Díaz de la Rubia shared what he observed while in China. "They are using HPC centers not just to do big simulations in physical science, but also for cloud computing and data analytics. Cloud computing was pervasive." Chinese HPC leaders, he said, responded to security questions by stating that something must be sacrificed to offer access for everyone. "That was both interesting and very concerning, Díaz de la Rubia said. "If you're working with sensitive simulations on a large scale for an industrial problem and you're in the cloud, there will be cyber security issues."

Hitchcock contributed that the DOE has been conducting experiments to determine the best uses for cloud computing, noting that its strength is time sharing. Being able to load your own operating system image, Hitchcock said, can be a good or bad thing. "It's a good thing if you know what your operating simulation should look like. It's a bad thing if you're a regular user because then you must be a system administrator as well as a user." Cloud computing works best, he asserted, if millions of people apply it to small jobs. "For large projects, it works sort of poorly. It will have a role, but it's not going to be a magical solution for everything."

Ashby added, "To me, cloud computing is really a business model. From a Council perspective, what I hope we can accomplish on this project is to help more people to take advantage of high performance computing." Once more people exploit HPC for competitive advantage, we will see more of a role for cloud computing vendor services, he said. Ashby, however, believes that dedicated computing centers and services will remain necessary for users concerned about proprietary or sensitive security data.

Dan Hitchcock, U.S. Department of Energy.

Díaz de la Rubia concurred that the focus of the Council initiative will be enabling more users to take advantage of HPC. He stressed that cloud computing is not the key to broader access to HPC, because more fundamental barriers remain. “It’s about partnership. It’s about bringing people in to learn and experience how to use the technology and take advantage of it, and then take it back into the companies to utilize it. Then we can work on business models that allow for broader access.”

Hitchcock led the next phase of the discussion, stating that HPC is in a critical transitional phase due to the changes in complementary metal oxide semiconductor (CMOS) technology. “The computers around the middle of the decade are going to look very different.” The chips will need to run at a much lower power density, he explained, which means that chip manufacturers will lower feature size.

That does two things, Hitchcock suggested. “First, it means that the challenges of parallel programming that are common to HPC are heading toward your laptop. We’ve made virtually no progress in making parallel programming easier over the past 20 years.” Second, he said, changes in CMOS technology will turn energy cost ratios upside down between operations and moving data. “It used to be that operations were the expensive thing. But now or by the middle of the decade, the operations will be a tenth of the cost of moving the data five millimeters on the chip—and that changes the structure of everything. It changes 80 years of American analysis. It means the codes that were designed for the old architecture will run extremely poorly on the new architectures.”

The change also presents a great opportunity, he said, because the power requirements to make the leap from petascale to exascale computing would be extremely burdensome (approximately 300 megawatts) using chips with current power efficiency levels. Hitchcock stated that current efforts aim to improve efficiencies to a level where an exascale computer could operate at about 20 megawatts.

“That also means that you could have a petascale computer in an office, plugged into a 240 volt circuit,” he said. Hitchcock explained that such capability would be an enormously powerful tool for business, enabling them to build better products faster. He emphasized that the capability will not become widely available without government leadership because “the vendors’ product road maps are based on their quarterly profit and loss statements that go to Wall Street.” There is too much risk and time involved, Hitchcock asserted, for companies to invest in these advances alone or through incremental means.

The DOE is working to devise incentives and/or risk reduction strategies that would encourage semiconductor and computer vendors to invest, he continued. Other efforts include striving to make software more widely available and incorporating the best-applied mathematics and computer science into software used by physicists and material scientists. "Every year, we pick four codes that our advisory committee vets and try to at least double the effectiveness of the software, enabling us to either solve the same problem in half the time or solve twice as hard a problem in the same time." Hitchcock noted successes under the program and reminded TLSI participants that the software is open source.

Interaction between the government and industry, however, presents challenges, he said. As it interacts with firms on HPC software and software integration services, the DOE builds an expertise that could potentially compete with the private sector. Hitchcock said that the department is exploring how to incentivize small and medium-sized businesses to assume such a role between the DOE and industrial users. "It is really important to have people who know where HPC opportunities are and how reach out to industry effectively. There aren't many people who both understand our world and the world of building tractors or farm implements, for example. If the Council on Competitiveness can help connect us with such people, then we may have ways to help the Council realize its goal of more widespread HPC usage."

Hitchcock further explained that the DOE has authority to hire people temporarily from universities and non-profits under the Intergovernmental Personnel Act, but not from companies. "If there was a way to bring industrial managers into the Office of Science or our facilities for a year or so, they'd take valuable insights back to their firms." He suggested that the DOE also might reach out to business schools to insert HPC management insights into their curriculums.

Andy Karsner, Manifest Energy; Tony Tether, Council on Competitiveness; and Klaus Hoehn, Deere & Company.

Wince-Smith thanked Hitchcock and asked McIntyre and Hoehn to offer brief remarks. McIntyre announced that the Obama Administration has formed a public-private partnership with Lockheed Martin, John Deere, General Electric and Proctor and Gamble to help small and medium-size manufacturers use modeling and simulation. "It is a $5 million project over 18 months," McIntyre said. "The Council has brought this consortium together in order to move modeling and simulation into the supply chain and down to small manufacturers." She followed up on Hitchcock's remarks by saying that the Council also will convene industry leaders on building the business model for exascale computing.

Hoehn offered two suggestions, drawing on insights from Germany. First, he advocated that the Council articulate a unified aim of its initiatives under one umbrella that is compelling and action-forcing. As an example, he noted that there is an understanding in German society that their future depends on exports. "It's deeply ingrained in the society that they will be the No. 1 exporter, not only in terms of quantity, but sometimes even more on quality." Hoehn believes that the Council could help build a similar culture here, though not necessarily centered on exports.

Second, he suggested that the TLSI would be well served to consider components of innovation models in other nations as the Council considers how to improve the U.S. system. One such example, Hoehn offered, are the Fraunhofer Institutes in Germany. He explained that after World War II, academics in Germany could not agree on whether universities should focus predominantly on fundamental or applied research. "That was never resolved, but it did create one branch of academia that concentrates on fundamental research. The other path toward applied science is pursued at the Fraunhofer Institutes. Right now, there are 56 Fraunhofer institutes serving different aspects of applied science. They are a pretty unique structure, globally." Hoehn indicated that he would be willing to take a TLSI group to visit some of the institutes in 2012. Malshe and Rottler supported this idea, with Rottler adding that the group also should consider visiting some of the Helmholtz Institutes in Germany doing collaborative work.

Lifka complemented Hitchcock for his remarks and for the DOE's efforts to improve codes and work with industry. He agreed that the labs should be more open to industry, but suggested that "you could turn it around and say that industry should open up to the labs." Lifka suggested that the labs could become training grounds for future industry employees—with lab personnel joining firms rather than industry personnel being hired temporarily by the labs. "I think the opportunity is both ways and would take a little creative thinking, but that might allow the cross pollination to happen within the law." Díaz de la Rubia agreed, noting that a recent partnership between the Lawrence Livermore and Sandia labs seeks to facilitate Lifka's suggestion.

PART 2: FINDINGS FROM TLSI DIALOGUE 5

Luncheon Keynote

Dr. Arun Majumdar
Senior Advisor to the Secretary
Director, Advanced Research Projects Agency—Energy (ARPA-E)
United Stated Department of Energy

Dr. Arun Majumdar, U.S. Department of Energy; Deborah L. Wince-Smith and Chad Evans, Council on Competitiveness; and Bart Gordon, K&L Gates and Council on Competitiveness.

I am delighted to see that the Council's pre-report to this dialogue highlights ARPA-E's programs. We also have an annual report on our website that gives an idea of how we are thinking about clean energy—trying to focus on technologies that reduce cost so we can scale without subsidies and enable sustainable businesses. The report also details the kind of projects that we have funded and gives insight into the speed and efficiency of our operations.

Before I begin my remarks, I would like to acknowledge Congressman Bart Gordon. I call him one of the founders of ARPA-E. I'm just the first babysitter. Nevertheless, the last two years have been absolutely fascinating, and I tell people this is probably the best job I've ever had. I'm proud of the team we've put together and our potential to make an impact, though we still have a long way to go.

I would be remiss if I didn't talk about the budget. We have our first appropriated budget for this year, fiscal year (FY) 2011. A lot of people on Capitol Hill worked very hard, both members and staffers, to get a line item for ARPA-E in the budget. This is a very important step, and I'm deeply thankful for that. While the amount is not exactly what the president asked for, that's fine. At least we're there, and I thank all the members of Congress who were involved in that. The FY 2012 process is underway right now. Hopefully when the debt ceiling discussions are resolved, we can talk more about the FY 2012 budget for ARPA-E. The president is deeply supportive. It is a top priority for Secretary Chu, and the president has said openly that he wants to protect ARPA-E. The vice president is also deeply supportive. So I can't ask for anything more.

I have spent an inordinate amount of time in the halls of Congress, essentially informing my board of directors what we do and what the value proposition is of ARPA-E. I think that has led to some bipartisan support for our efforts in both the Senate and House. But of course we are in difficult times and we don't know yet how we'll fare in FY 2012 and 2013.

We have several projects that came out near the end of April, and within a few days, we will issue a new funding option announcement. The kind of projects we're looking at, just to give you a few examples:

(1) radar: how to create motors and generators without the use of radar, completely eliminating its use. That would be creative destruction if you could do that; (2) new ways of managing the grid. This is computation, communication and controls that will build an operating system for the grid. It is an empty heart problem and very hard. The grid could be real time, potentially—the technology exists. We doubled down on things like power electronics because we feel it is an area of under-investment with potential for breakthrough technologies.

We also did that for energy conversion efficiency, especially related to solar technologies. We created the Sun Shock Initiative. This is a joint DOE program between ARPA-E, the Office of Energy Efficiency and Renewable Energy, and the Office of Science. Its goal is to reduce the cost of solar electricity to five cents per kilowatt hour by 2017. If we do that, I think solar would scale without subsidies anywhere in the world. Today the cost is at least 15 to 20 cents per kilowatt-hour.

There are many other programs, such as the Plant Engineering to Replace Oil programs, called PETRO. These are the kinds of the things where we are taking a new look at issues and approaches. We had an energy innovation summit recently with more than 2,000 people. Attendees included not only scientists and engineers, but people from the business community, investment community and Capitol Hill. We need all the stakeholders there to showcase not only the hundred or so ARPA-E technologies, but also to discover what we might have missed. It is important for the whole ecosystem to flourish.

We've also established a partnership with the Department of Defense, which is a very important step. There is a high need for energy in the DOD, and if you could use that scalability to bring down the cost of alternatives and make them commercially compatible, this would be a good thing. This was enabled by former Secretary of Defense Bill Perry, who has been sort of a mentor for me. This is the first step of hopefully many more. The partnership was announced at the summit by Secretary of the Navy Ray Mabus. The power systems covered by the partnership will not just be transportation-based, but stationary as well.

We've also established a partnership with utilities. It is really important for the utilities and the regulators to understand what is technologically possible and coming down the pipeline. Conversely, it is important for us to understand where the gaps are in the utility space and what kind of walls they're going to hit. Many of the assets like transformers are beyond their predicted lifetimes, for example. There are many other such problems. Duke Energy, in fact, approached us because they want to better understand which technologies are out there. We don't work with only one utility, however, so we have opened it up. The Electric Power Research Institute is part of it now, and others are going to join.

One of the criteria for ARPA-E investing in something is an expectation that the private sector will continue investment once the risk has been reduced. Our job is to take risky propositions—not foolish ones—but risky propositions and see whether they work out. In many cases, there has been 12 to one leveraging of private funds. The average is about four to one. That's a good sign. There are projects which are not working out, and I've told Congress that I will terminate them and not go down a blind alley. Since they all started from the Recovery Act, the money will go back to the Treasury.

There are some really wonderful early successes; things that have gone from ARPA-E straight to loan guarantees and now to a manufacturing plant. I know that the Council deeply cares about manufacturing, and I look forward to partnering with the Council on this issue. I think it is absolutely critical that we cover the whole innovation chain from R&D innovation to manufacturing deployment.

We are now recruiting like crazy because by statute, people have to leave ARPA-E. The first team is likely to leave next year, so we are trying to get the best talent we can and get a team that is even better than what we have today. Our first goal of recruiting is to ask whether the person is higher than the average. We are recruiting really talented people. We are holding several workshops and creating new programs, but we have spent a lot of time on outreach.

In conclusion, as I've said, I have spent a lot of time on the Hill, and I think so far we have gotten fairly positive reviews. If you know of any negative reviews, please let me know, and we will reach out to try and address them. But the response so far has been a lot of positive things.

That's a quick report. Thank you very much for all your support, and I want to say that I really look forward to working with the Council, especially on the manufacturing issue, because I think that it is a national priority that we have to address.

Discussion

Wince-Smith and Little thanked Majumdar for his remarks and his service to the country. Wince-Smith asked Majumdar to share a story about the number of proposals ARPA-E received in response to its first call for proposals. "I think it was a success metric of ARPA-E's vision," she said.

Majumdar noted that the success came before he joined the agency, but that "4,000 proposals came in and overloaded the DOE computer system. We had to create new software, which now other parts of the government are using. I think there is a lot of value in simply asking people to give us your best ideas. The process has to be managed, though, and we are not staffed enough. If 4,000 came in the first round, we'd probably get 10,000 the next time." Majumdar explained, however, that the agency has learned techniques from the Gates Foundation to manage and evaluate so many proposals. "We hope to use those techniques if we have enough budget."

Wince-Smith relayed the earlier conversations about U.S. talent needs and noted deficiencies expected in energy fields. "We are expecting half of the utility workers to retire in the next few years," she shared. She asked Majumdar to comment about interagency efforts to cultivate talent. He replied by agreeing with Wince-Smith on the scope of the problem and noting that the issue is bigger than one agency.

He explained that ARPA-E's criteria for recruiting talent are not limited to people with backgrounds in energy fields. "Smart people will figure out what to do in the energy field in a new way." To the larger issue of human capital in the United States, he noted roles for several players like the NSF, universities and community colleges. For science and engineering fields, he emphasized that attention has to reach back at least as far as the middle school level. He expressed concern that for many problems, like managing the grid, there will be too few students entering STEM fields.

Andy Karsner, executive chairman of Manifest Energy and distinguished fellow at the Council, shared an experience he had with a venture capital firm interested in one of the companies funded by ARPA-E. "As part of our due diligence, we asked whether we could we sit in on the quarterly program with ARPA-E conducted by your project manager. Surprisingly enough, the answer was yes." Karsner complimented Majumdar for his agency's openness and indicated that a collaboration began between his group and the company.

Majumdar thanked Karsner and said that "one of the things about ARPA-E from the beginning was people asking me, who are your customers? My reply was that anyone who uses energy or is in the energy business ought to be a customer, including government agencies like the Department of Defense. Because most of the energy sector is in the private sector, to get a commercialization group and provide the connective tissue between what happens in ARPA-E and what happens in the private sector is absolutely critical. The design of the programs, where cost is an issue, is fundamental. We must bring down costs and focus on technologies that have a chance to scale without subsidy. And so we must be connected to the investment community, to the utilities, to the private sector—businesses large and small. That is part of our DNA."

Díaz de la Rubia asked whether ARPA-E is looking at how HPC and simulation would apply to the energy sector. Majumdar replied that to develop the next generation of solid state transformers, they would have to be tested to ensure their safety. HPC could be a part of that process and the agency's partnership with utilities. He also believes that HPC could tackle problems under ARPA-E's Green Electricity Network Integration program.

Gordon complimented Majumdar for his efforts to communicate the value of ARPA-E to audiences of different viewpoints, noting his efforts with Congress and think tanks like the Heritage Foundation. Gordon emphasized that funding for ARPA-E was still at risk. "We are through that very critical element of the program existing," he explained, "but when ARPA-E was proposed, it was supposed to be a billion dollar per year program to start and then ratchet up." Although President George W. Bush signed the bill to create the agency, Gordon said, no money came through until the stimulus bill. "The House only authorized $100 million, making it more challenging to recruit the kind of folks the agency will need if they don't think there's going to be the money to do these jobs. There needs to be a real push for the legitimacy of ARPA-E and the funding during this real critical period."

Gordon stated that ARPA-E's importance extends beyond its mission. "It is a model of how federal agencies can work better, faster, more efficiently and more collaboratively." He noted that some in Washington are discussing whether the ARPA-E model could be applied to education and health, for example.

Tony Tether, distinguished fellow at the Council and former director of the Defense Advanced Research Projects Agency (DARPA), stressed the importance of ARPA-E remaining on the leading edge. "I hope that ARPA-E is never perceived as anything short of addressing a national state of emergency, because that's where we are in terms of energy. The last thing I'd like to see is that you become a process or part of a process, or that every agency gets an ARPA-E." DARPA's success remains tied to advanced research to defend the nation, Tether said, and he believes that America's reliance on offshore energy has hurt the country deeply and constitutes a national emergency worthy of ARPA-E.

Shangraw asked Majumdar to identify the key factors that have made ARPA-E successful to date. He agreed with Tether on not creating similar research agencies for every department, "but if we are going to stand up another one for education, which we may need from a national crisis perspective, what are the things that would make it successful?"

Majumdar replied that in the energy area, it is important to identify gaps. "There is a gap in translating science into breakthrough technologies. We have been going down the learning curve with certain technologies like alkaline batteries, but we were not creating new learning curves." That requires risk taking that was not occurring in the market, he stated. Majumdar also praised the statutory provisions provided in the America COMPETES Act that authorized ARPA-E. "We can hire without following civil service laws, and you can thereby hire quickly. Talent is not going to wait for six months for the HR process to run. Also, there are term limits for employees—three to four years." Majumdar indicated that the term limits lend a sense of urgency for a director to "get things done." He also stressed how important it is that administrative and technical people share a same sense of mission. Finally, he repeated that it is "absolutely critical" for ARPA-E to be connected to customers in the energy sector who see value in the engagement.

PART 2: FINDINGS FROM TLSI DIALOGUE 5

Exploring the Frontiers: Emergent Technologies for Future Competitiveness

Little opened a discussion on technology frontiers to examine whether Americans are focused adequately on key technologies and grand challenges. Little introduced Shangraw and Karsner to join him in offering remarks.

Before offering his thoughts on specific technologies and challenges, Shangraw reflected on the dialogue, noting that "we have many organizational, structural, incentive and cultural issues to address, in addition to dealing with technologies." The first question posed by the Council for this part of the dialogue, he reminded, is "which technologies are key to U.S. competitiveness, yet not being pursued with sufficient intensity or investment?"

Shangraw stated that his list was defense-centric, noting that the DOD is a large purchaser, supplier, builder and developer of materials. "If you can get DOD to invest in a technology, they're more likely to buy it and create a market." Once a market is created, the technology is often applied widely for non-defense purposes, he said. Shangraw offered the following list of technologies:

- Next-generation antibiotics and antivirals
- Next-generation vaccine technologies and manufacturing platforms
- Regenerative medicine
- Biosurveillance and biometrics (public health and counter-terrorism)
- Synthetic biology
  - novel materials and new bioprocesses that preserve natural resources
  - medicine, agriculture, energy
  - bioremediation and waste streams

Rick Shangraw, Arizona State University, and Steven Meier, Lockheed Martin Corporation.

- Food, feed and water resources security (supply and safety)
- Cognitive biology and human-to-computer (or machine) interface technologies
- Ubiquitous sensor networks
- New concepts and methods for managing massive data in multiple domains
- New analytical algorithms and modeling of non-linear phenomena
- Cyber-defense, particularly as it relates to critical infrastructure

Advancing these DOD projects would benefit other sectors like health care or energy, Shangraw observed. The United States, however, has to find more platforms for demonstrating and piloting these technologies, he said, as the process remains "incredibly inefficient." He reminded TLSI participants of the two valleys of death discussed throughout the dialogue—one at the invention to innovation stage, and another at the stage of manufacturing at scale.

The second question posed to the panel, Shangraw relayed, was to identify technology-dependent grand challenges with major deficits in current technology. As with the first question, Shangraw believes that the larger issues are cultural and structural rather than technology-specific, but he did identify a list of challenges:

- Aging populations in Organization for Economic Cooperation and Development (OECD) nations
  - insufficient health care personnel trained in geriatric care
  - inadequate development of remote health status monitoring technologies
  - new delivery systems for effective polypharmacy and compliance tracking
- Escalating risk of global epidemics/pandemic
  - human, animal and plants (need for an integrated 'One Health' strategy to integrate human, veterinary, agricultural and ecological health systems)
  - new surveillance tools for early warning of epidemic risk and new disease patterns arising from climate change
  - 21st century vaccine platforms to replace current outdated production methods which lack the agility to respond rapidly to emergent threats
  - new incentives for industry investment/re-engagement in antibiotic R&D to address the urgent problem of antibiotic-resistant infections
- Future food shortages created by projected global population growth
  - accelerated development of new agricultural traits for major crops to support enhanced yield and adaptation to anticipated environmental changes caused by climate change (heat and drought-tolerance; pest resistance and changes in insect and parasite vector-borne crop infections due to new geographic range)
  - new vaccines for livestock in Africa, Asia and South America to address endemic infections and the adverse impact on yield, plus the growing risk to global agriculture from epidemic spread
- Access, availability and safety of water resources
  - synthetic biology to design novel microorganisms for bioremediation of contaminated sources
  - improved waste stream management to reduce toxic hazards from industrial processes
- Energy
  - storage
  - smart grid and next generation transmission
  - alternate liquid fuels
- Terrorism / Security
  - reliable technologies (e.g. novel biometrics, social network analytics, new remote strike capabilities) to tag, track and locate terrorists and materiel
  - cyber-disruption, cyber-war and risks to critical infrastructure and populations
  - cold atom (quantum interferometry) technologies that can provide far better than GPS-level position and timing accuracy.

- Managing massive data (multiple domains)
  - international standards for ontologies/semantics data formats, database curation, annotation and analytics to optimize interoperabilities, validate authenticity and data provenance and robust security for cloud-based databases
- Technological-literacy for sustained workforce competitiveness and rational public policy
  - new investment and incentives for K-12 STEM education
  - radical reform of undergraduate/graduate curricula to create workforce candidates with competencies to engage in complex inter-disciplinary problems
  - infusion of new science-and evidence-based skills into regulatory agencies to build competence for evaluation of emergent technologies
  - increase of at least a ten-fold in work visas and new mechanism for accelerated residency/citizen status for individuals with STEM and/or other key strategic skills
  - elimination of Patriot Act residency restrictions for individuals receiving technology-based education in the United States
- Adaptation / preparation for climate impacts and other potential disasters
  - improved resilience for agriculture, water, critical infrastructure, transportation

Little offered a different perspective based on GE's industries and institutions. He noted that since the last TLSI dialogue, the Obama Administration indicated some of its innovation priorities, including bio- and nanotechnology, HPC and grand challenges around energy, health care, education and space.

Mark Little, GE.

"In our TLSI discussions, we talked about additional priorities around defense, homeland security, food issues and critical materials," Little summarized.

Energy is one GE's top priorities, Little said. He observed that energy policy works to balance issues of supply, cost and emission. He complimented the government speakers at the dialogue, but stated that it remains unclear what they believe the proper balance should be among those competing interests. He offered the U.S. wind industry as an example, noting that it has been driven by a tax credit. The uncertainty of whether the credit will be renewed each year "caused fits and starts in the industry that were very difficult." After a few years of sustained support, he said, the industry took off. "We built up capacity with funding from the DOE and have seen a transformation." During the past five years, Little relayed, wind technology has advanced to the point where "even without subsidies, we are very close to being competitive with natural gas fired turbines, which is the most efficient way to generate power. The reliability is way up, and costs have come down."

He noted that similar progress is underway in solar technologies, and that GE is investing strongly in a business that sprang from technology developed in the national laboratories. "We are going to build an industry around that." Little also noted the important role that government policy will play in the utilization of shale gas.

Less encouraging, Little said, was uncertainty about lighting efficiency policy. Government efficiency requirements are knocking out the incandescent lighting business, he explained. Rather than arguing whether the ban on incandescent lights was good or bad, Little pointed out the potential impact of uncertainty. "We have taken out or are in the process of taking out all of our lighting plants. The issue is we have invested a gigantic amount of money in taking out these plants." If the efficiency policy were reversed, Little emphasized, "the net affect would have been to wipe out the U.S. industry for incandescent lighting and shift it all to China."

Little commented briefly on health care technology policy, noting that industry should focus on reducing cost and raising quality. The National Institutes of Health have been a powerful force in raising the world's level of health care, he said, but the Food and Drug Administration has been much to slow and "is causing a shift in innovation to Europe and even to places like India."

Another technology shift relates to manufacturing, Little asserted. He described the movement within GE and other companies to move a greater share of their manufacturing back to the United States as conditions become more favorable and companies consider additional factors that recalculate the total cost of production. "We have decided to in-source core manufacturing around our old-line appliance business." Little described a good partnership with labor and government in moving production from Mexico to Louisville, Kentucky. He anticipates a rapid shift back to the United States as other companies make similar calculations.

Karsner complimented the other speakers and strove to build on their insights by offering a macro perspective, particularly on energy. The grand challenge he sees is the connectivity between energy and commodities—a global resource race to which Washington is poorly attuned. America is engaged in an exercise to mitigate the bleeding, Karsner said, in contrast to the long-term planning that nations like Germany pursue "with real performance metrics and a grand vision." He asked rhetorically whether the United States has moved closer during the past three years to addressing the grand challenges the DOE was designed to address. "The answer is no. In fact, we're probably worse on every count." Karsner cited greater emissions, more reliance on foreign oil, and a weaker economy as evidence, despite large investments.

Karsner also lamented that the country seems to lack a positive stretch goal like the moon shot to drive U.S. technological leadership. Instead, the overriding challenge today is negative, he said. "How do we avoid being broke? How do we pay our bills next month? It really is unfortunate, and we must get out of this hole." Karsner also observed a common theme throughout the dialogue of "how do we organize ourselves for the task? At what point are we going to say that we have systemic failure in our organizational capacities as a nation to compete irrespective of our investment in the science and technology complex that we designed? We have never left the cold war posture in which most of these institutions were built." He described the transition as very slow, noting that ARPA-E is a great step but, with a $200 million budget, still a very small step stacked against the challenges to be met.

"The grand vision has got to be how do we restore leverage to this country in such a way that it can legitimately, sustainably plan and manage the standard of living that everybody is accustomed to? Maybe that's too low of a goal. We might add cleaner air, a safer environment or a more independent and

Andy Karsner, Manifest Energy, and Arun Majumdar, ARPA-E.

secure future." Karsner asserted that America risks a decline if the vision or action to achieve the vision is inadequate. The Council should lend its weight to this challenge, he stated.

A significant component of the challenge, he emphasized, is making a better allocation of effort and resources so the private and public sector not only work together more effectively, but also avoid duplicating efforts. He described some DOE pursuits as redundant to private sector efforts that enjoy more robust funding, more planning and more attunement to application in the market. Karsner believes that the DOE should devote more resources to "the indispensable things the government can do that the private sector cannot. That doesn't mean choosing specific technologies—the Department has become in the last 36 months the largest private equity investor in the world of energy. We have a system that writes checks of $600 million to single company's balance sheet that goes broke in 24 months. That system is not sustainable." He expressed concern that a political backlash would halt not only those programs, but also limit constructive programs on which the DOE should focus.

He noted value in DOE efforts, such as basic research in bio- and nanotechnology; leveraging HPC assets to generate energy breakthroughs; and pursuing petroleum security. "But right now, they're doing everything, and we don't have enough money to do everything. There is an opportunity, however, to employ a little creative destruction, stand back, and reorganize to compete with milestones and metrics and timelines that are feasible. It sounds more mundane than moon shot, but we're not in a position to fantasize. We're more in a housekeeping mode, and the Council should help the government face its systemic failures."

Discussion

Ashby thanked the discussion leaders and weighed in on a three technology areas he identified as priorities. He also agreed with Little and spoke to the importance of multi-year policy and funding stability once priorities are set in order to attract technical talent and encourage private sector investment.

Priorities put forward by Ashby and his observations/questions:

- Rare earth substitutes or alternatives
  - important for defense and consumer technologies
  - China controls 97 percent of world's rare earth resources
- Clean energy and electricity
  - what is future for nuclear power in United States and where does the DOE stand?
  - might be opportunities to make technology leapfrogs
  - what is to be done about storage of nuclear materials?

- Cyber security
  - cyber infrastructure increasingly interdependent—economic and military
  - question exists whether United States is investing adequately, including in research

Davis agreed with many of the technology priorities identified, but offered an additional list based on his engagement with manufacturers:

- Distributed intelligence technologies
  - brings information in real time at the point of decision
  - requires workforce trained to make informed decisions rather than perform routine tasks
- Low cost sensors
  - offers more and different kinds of information
  - information fusion challenges result
- Reference common architecture for data across factory floor and supply chain
  - aggregation of shared platforms
  - research required on what business model works for such collaboration technology
- Test beds

Johnson agreed with several points made by Karsner and observed that political leaders since President Kennedy have been unable to inspire the same kind of national will and drive that he generated toward the space program and landing on the moon. "I think it had a lot to do with his eloquence, but it had a lot more to do with the position of the United States in the world," Johnson said. "If you think about 1957 and Sputnik roughly 12 years after World War II, Americans were devastated that the atomic weapon was stolen by the Soviet Union and fearful that it might be launched to our soil." That fear drove a sense of urgency that is absent today, he suggested.

"Is it only when the standard of living in the United States begins to drop that we as a nation pull it together and figure out we've got to behave differently?" Johnson asked rhetorically. He echoed Karsner's point that rather than spreading resources so broadly across different objectives, the TLSI might suggest specific challenges and revolutionary technologies for focused effort that do not require waiting until fear overcomes the nation.

Majumdar stated that Johnson's comments about national security resonate and that in some cases fear remains a motivator. "We tend to think that the government and Congress no longer have the resilience and willingness to invest in big ideas and missions for the future. The Cold War is over, but nevertheless the nuclear threat is still out there, and it is a real national security concern. Proliferation is a real issue, and people recognize it. As the president has said, as long as nuclear weapons remain on the planet, this country is committed to maintaining a strong, safe, secure, reliable deterrent for itself and its allies. Congress agrees, and the country is going to invest an additional $85 billion over the next decade to revitalize the nuclear weapons program. That is proof that if you have the right incentive, the country is still able to come together."

Wince-Smith concluded the dialogue by thanking the co-chairs, participants and Council staff. She praised the participants for raising important competitiveness issues and discussed how the TLSI priorities will continue to be integrated with other Council projects, particularly the USMCI.

Conclusion

The Council hopes that TLSI Dialogue 5 will expand the stock of ideas already put forward on how to improve America's innovation enterprise. Several participants have commented that the nation would benefit from more coordinated policymaking and priority setting. This report aims to give a reasonable overview of how decisions are made, what priorities have already been identified, and how those priorities are being addressed. By laying this foundation, the Council seeks to elicit informed insights on how America can do better, particularly in the face of ever more capable competitors, severely limited budget flexibility, and an economy still struggling to produce the jobs and growth sought by its leaders and citizens.

TLSI Dialogue 5 Participants

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Deere & Company

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Senior Vice President and Chief Technology Officer
Lockheed Martin Corporation

Dr. Mark Little, *Co-Chair*
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Mr. Montgomery Alger
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The Honorable Deborah L. Wince-Smith
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Resolve.

Dialogue 6:
Changing the U.S. Innovation Landscape—
the Path from Words to Deeds

October 24, 2011
U.S. Naval Academy
Annapolis, MD

Letter from the President

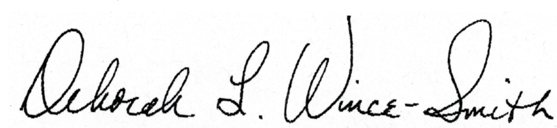
On behalf of the Council on Competitiveness, it is my pleasure to release *Resolve*, the sixth report of the Technology Leadership and Strategy Initiative (TLSI). The TLSI brings together leaders from America's leading companies, universities and laboratories to set a new national agenda for research, technology, and commercialization.

The initiative is led by Klaus Hoehn, vice president, advanced technology and engineering for Deere & Company; Ray Johnson, senior vice president and chief technology officer of the Lockheed Martin Corporation; and Mark Little, senior vice president and chief technology officer for the General Electric Company.

This report is divided into two sections. Section one, the "pre-report" sets the stage for the dialogue. As the Council moves more into an implementation mode, section one summarizes key developments across the public policy landscape and presents recommendations from the TLSI Working Groups. Part two captures the ideas put forward during TSLI Dialogue 6, held October 24, 2011, at the United States Naval Academy in Annapolis, MD. Dialogue 6 explored naval research, delved into linkages between art and science achievement, discussed the TLSI recommendations, and received expert updates on the federal outlook for science and developments in high performance computing. Participants also were honored to learn directly from midshipman about the research underway at the United States Naval Academy.

The Council also expresses its sincere thanks the U.S. Department of Defense for its support. The Council is committed to help the Department bring new technologies into practice faster and more efficiently—thereby strengthening America's industrial base and our national and economic security. The TLSI dialogues are designed to be an open exchange of ideas. The opinions and positions presented in this report are those of the Council or the individual who offered them. The opinions and positions in the report do not reflect official positions of the Department of Defense or other government agencies.

Sincerely,



Deborah L. Wince-Smith
President & CEO
Council on Competitiveness

Part 1:
Setting the Stage for TLSI Dialogue 6

PART 1: SETTING THE STAGE FOR TLSI DIALOGUE 6

Introduction

Roughly 640,000 years ago, one of the greatest known volcanic eruptions occurred—2,400 times larger than Mt. Saint Helens—spewing ash over much of the present day western United States. The source of this explosion was an enormous and still active magma chamber resting beneath Yellowstone National Park, the source of the park's unique geology of geysers, boiling mud, steam vents and thermal pools.

In the mid-1960s those thermal pools became a source of interest to Thomas Brock, a microbiologist from Indiana University supported by the National Science Foundation. Brock was examining photosynthetic life in the pools, finding that such life could survive at an upper limit of about 174 degrees Fahrenheit (73° Celsius). Unexpectedly, Brock discovered that other forms of life could survive at even higher temperatures. In 1966, he collected a sample in Yellowstone's Mushroom Spring (figure 1) from which he and a research assistant were able to isolate Thermus Aquaticus, then an unknown bacterium capable of thriving in the hot, sulphuric environment.[1]

Brock's discovery kicked off a hunt for other "extremophiles" that live in places previously thought unable to support life—places with high or low temperatures, high acidity or high salinity. The discoveries not only expanded knowledge about the diversity of life, they also enabled scientists to examine characteristics of the newly discovered life forms. Thermus Aquaticus turned out to have a very important characteristic.

Almost a decade after Brock's discovery, scientists isolated taq polymerase, an enzyme from Thermus Aquaticus that remains stable at high temperatures. In the early 1980s, scientists at the Cetus Corporation led by Kary Mullis determined that this enzyme could be used in a process to replicate sections of DNA in large quantity from a very small sample. The heat-reliant process is known as a polymerase chain reaction (PCR). Utilizing taq polymerase, PCR dramatically improved the accuracy, speed and cost of conducting DNA analysis and won Mullis a Nobel Prize for Chemistry in 1993.

1 Brock, Thomas D. *Value of Basic Research: Discovery of Thermus Aquaticus and Other Extreme Thermophiles*. Genetics Society of America, 1997. http://www.genetics.org/content/146/4/1207.full.pdf+html

Figure 1. Mushroom Spring, Yellowstone National Park

Figure 2. Thermus Aquaticus

PCR has become instrumental in health testing and research, law enforcement, and research in several fields. PCR can determine the presence and severity of viral or bacterial infections, it can detect variations in genes, and it can help match donors and transplant recipients. The technique is advancing detection, understanding, and/or treatment for things like AIDS, cancer, Lyme disease, hepatitis, ulcers, sexually transmitted diseases, tuberculosis, muscular dystrophy, and many other ailments.

Because PCR can identify and copy very small amounts of DNA even if they are old, the technique is crucial for law enforcement and forensic science. DNA fingerprinting of blood, skin or hair can be used to establish suspects' presence at crime scenes. Conversely, the technique has been used to establish the innocence of people wrongly imprisoned.

Other scientists like archaeologists, botanists and biologists use PCR to trace human, plant and animal migrations, as well as to understand evolutionary mutations that occurred over centuries.

The development of PCR offers another illustration of how many of the biggest breakthroughs in American innovation emerged from a mutual reliance of several actors over time: researchers supported by federal science agencies, corporate executives and investors working for profitable breakthroughs, and sparks of insight by university-trained scientists. As with many innovations, creative people built on the original breakthrough and discovered important new applications for the technology.

The Council on Competitiveness brings together America's top technologists through the Technology Leadership and Strategy Initiative (TLSI). The initiative aims to accelerate the pace and volume of U.S. innovation by enabling new ideas to move to market more effectively. TLSI leaders also are examining grand challenges for which technology will play a leading role in advancing or preserving Americans' quality of life—and often the quality of lives across the globe.

Steve Jobs once said that innovation distinguishes between a leader and a follower. The Council is dedicated to ensuring that Americans continue to lead.

PART 1: SETTING THE STAGE FOR TLSI DIALOGUE 6

Recent Developments Across the Innovation Policy Landscape

The TLSI is resolved to drive change in the U.S. innovation system. TLSI Dialogue 6 should begin a shift from a discussion and recommendation mode to a policy education and implementation mode. Fortunately, action is already underway on several topics of interest to TLSI participants, spurred in part by conversations with policymakers and those of other groups. This report, therefore, will review some of the more significant developments on the policy landscape and share the latest input from the TLSI working groups.

Patent Reform

On September 16, 2011, President Barack Obama signed into law the America Invents Act. The bipartisan legislation represents the most significant reform to U.S. patent law since 1836.[2] Some of the major provisions of the law will:

- **Move the United States from a first-to-invent to a first-to-file system.** The change is intended to speed and reduce the cost of determining patent rights. The change would align U.S. practices with other patent-issuing jurisdictions around the world. Supporters believe that a first-to-file standard will facilitate a more harmonized international filing system, enabling American inventors to obtain global patent protection more efficiently.

  Critics of the new law are concerned that smaller businesses and individual inventors could be disadvantaged relative to large corporations under the new system. The law attempts to address these concerns in several ways, including new administrative procedures and requiring U.S. Patent and Trademark Office (USPTO) to institute a patent ombudsman. The USPTO and the Small Business Administration also are required to produce reports on the impact the law has over time on small businesses and independent inventors.

- **Reduce the backlog of patent reviews.** Although the administration has reduced the patent backlog from more than 750,000 applications to 680,000,[3] the high backlog and related delays increase uncertainty for inventors and investors, hindering

2 United States Patent and Trademark Office. http://www.uspto.gov/aia_implementation/index.jsp

3 Office of the Press Secretary, The White House. http://www.whitehouse.gov/the-press-office/2011/09/16/president-obama-signs-america-invents-act-overhauling-patent-system-stim. September 16, 2011

Figure 3. Signing of the America Invents Act

innovation. The new law supplies rules and resources that the USPTO can use to accelerate the reduction of the backlog and decrease wait times.

- **Pursue higher patent quality through new USPTO procedures.** Prior to the new law's enactment, the USPTO adopted a new composite quality metric that expanded procedures to measure examination quality. The America Invents Act gives the USPTO additional tools to improve patent quality and allows patent challenges to be resolved in-house through expedited post-grant processes. Improving patent quality is a significant issue. The Organisation for Economic Co-operation and Development (OECD) reported recently that patent quality declined by an average of about 20 percent between the 1990s and 2000s, a pattern seen in nearly all countries examined.[4] Low quality efforts to protect minor improvements to products or services, says the OECD, overburdens patent offices, slowing time to market for true innovations.
- **Aim to reduce litigation.** The new law offers entrepreneurs streamlined rules and procedures to avoid patent litigation in hopes of a faster, fairer, and less expensive alternative to going to court. Several articles published by legal experts, however, point to aspects of the law that might shift the nature of litigation rather than reduce it. "Ultimately, only time will tell how the Act will alter the landscape of patent prosecution and litigation," writes Scott Plamondon of the Weintraub Genshlea Chediak Law Corporation.[5]
- **Offer a fast-track procedure for patent review.** USPTO director David Kappos described this concept to TLSI participants when he participated in TLSI Dialogue 3 in June 2010. In return for paying a higher fee (with discounts for small entities), the USPTO will guarantee an expedited 12-month turnaround instead of the average wait time of almost three years.

Many provisions of the America Invents Act do not all go into effect immediately, but will be staged into effect over three time periods (figure 4).

Research & STEM Education Budgets / U.S. Fiscal Environment

In 2007, President George W. Bush signed into law another bipartisan innovation law, the America COMPETES Act, that was heavily influenced by the Council's National Innovation Initiative. A primary objective

4 OECD Newsroom. *Science and technology: falling patent quality hits innovation, says OECD.* September 20, 2011. http://www.oecd.org/document/45/0,3746,en_21571361_44315115_48714477_1_1_1_1,00.html

5 Plamondon, Scott. *On the President's Desk: the America Invents Act.* September 8, 2011. http://www.theiplawblog.com/archives/-patent-law-on-the-presidents-desk-the-america-invents-act.html

Figure 4. Schedule for Rulemaking Under the America Invents Act
Source: U.S. Patent and Trademark Office

Group 1 Rulemakings (60 days or Less from Effective Date)	Group 2 Rulemakings (12 months from Effective Date)	Group 3 Rulemakings (18 months from Effective Date)
• Re-examination transition for threshold	• Inventor's oath/declaration	• First-Inventor-to-File
• Tax strategies deemed within the prior art	• Third-party submission of prior art	• Repeal of Statutory Invention Registration
• Best mode	• Supplemental examination	• Derivation proceedings
• Human organism prohibition	• Citation of prior art in a patent file	
• Patent term extension for drugs	• Priority examination for important technologies	
• Virtual and false marking	• Inter-parties review	
• Venue from DDC to EDVA for suits brought under 35 U.S.C. § 145	• Post-grant review	
• OED statute of limitations	• Transitional program for covered business method patents	
• Fee setting authority		
• Establishment of micro-entity		
• Prioritized examination		
• 15 percent surcharge		
• Electronic filing incentive		
• Reserve fund		

of the act was to gradually increase federal investment in research and STEM education through key agencies. Both President Bush and then-Speaker of the House Nancy Pelosi pledged to double funding over 10 years for the National Science Foundation (NSF), the core accounts of the National Institute of Standards and Technology (NIST), and the Department of Energy Office of Science. President Obama adopted the doubling goal as a candidate and followed through in his initial budget requests.

Congress supported the funding track from fiscal year 2007 through fiscal year 2010 (figure 5). Rising concerns about the country's debt and deficit, however, changed the political climate. A stalemate between the parties on entitlement and tax reform meant that the spending reductions demanded as part of the negotiations to raise the debt ceiling were taken from domestic discretionary accounts, of which the science budgets are a part.

In fiscal year 2011, total spending for the three agencies targeted for investment fell by $324 million. Pending appropriations legislation in the House would further reduce spending by $48 million in fiscal year 2012. Senate legislation would cut $179 million (figure 6). Relative to other parts of the discretionary budget, the cuts to these agencies were modest because the president and leaders in both parties understand the linkage between research, education, innovation and economic growth.

Figure 5. Funding for Research / STEM Doubling Plan
Source: Council on Competitiveness drawing on agency and congressional sources.

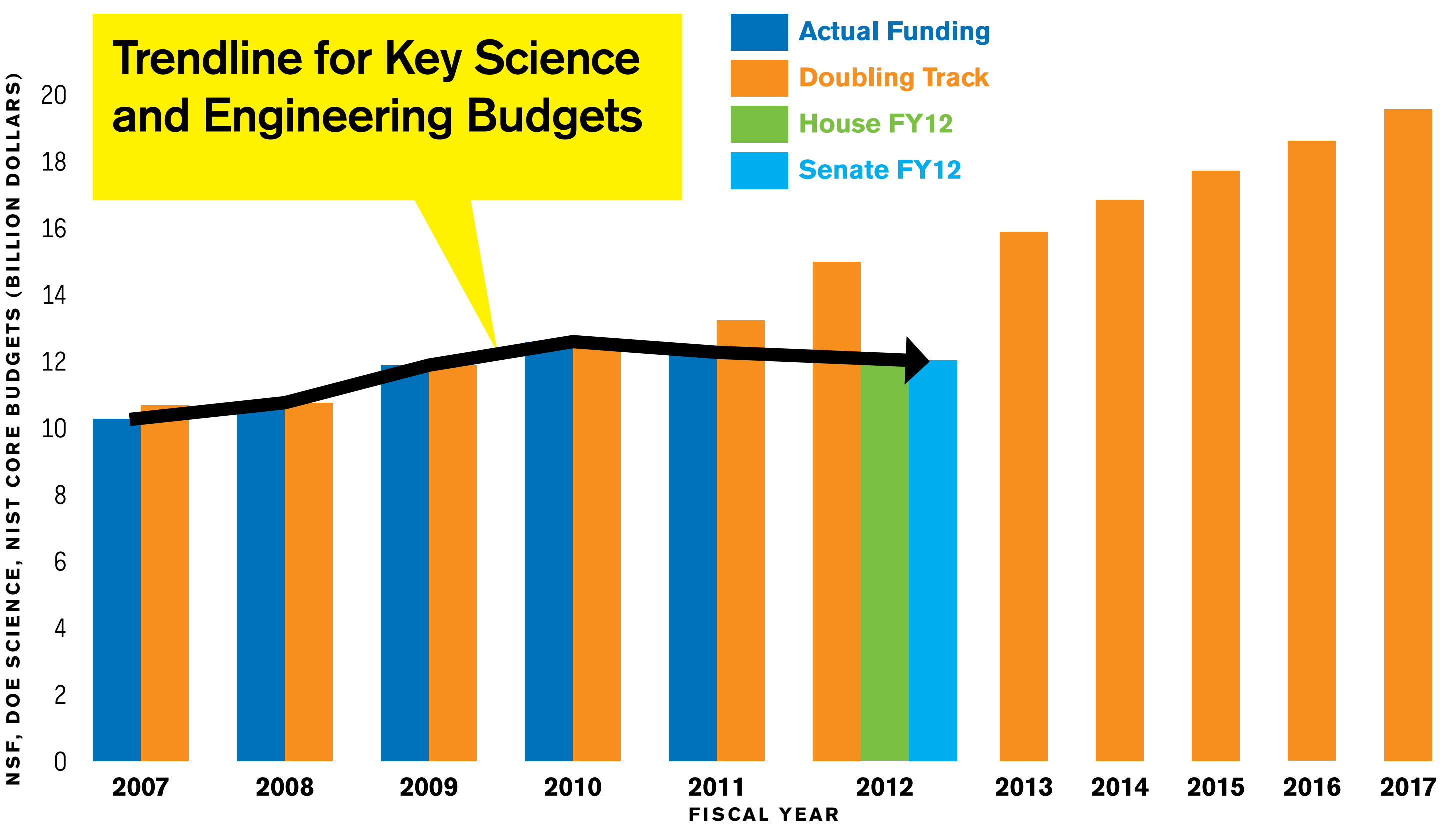


Figure 6. Funding for Key Research Agencies, Dollars in Millions
Source: Council on Competitiveness drawing on agency and congressional sources.

Agency	FY10	FY11	FY 2012		
			Budget	House	Senate
National Science Foundation	$6,972	$6,860	$7,767	$6,860	$6,698
Dept. of Energy Office of Science	4,964	4,843	5,416	4,800	4,843
NIST Core Accounts	668	577	766	572	560
TOTAL	**12,604**	**12,280**	**13,949**	**12,232**	**12,101**

Despite intellectual support for innovation funding among policy leaders, the risk of deeper cuts is very real. The compromise legislation to extend the debt limit established a Joint Select Committee on Deficit Reduction, known informally as the "Super Committee." This group of 12 lawmakers is tasked with proposing an additional $1.5 trillion in deficit reduction over 10 years. The committee must vote on a plan by November 23, 2011. If approved by a simple majority of the Select Committee, the House and Senate are required to vote on the plan by December 23, 2011, without amendments.

If the president does not sign $1.5 trillion in reductions into law, automatic cuts are triggered in 2013 to make up any difference between the enacted cuts and the $1.5 trillion target. The automatic cuts could include sensitive defense and medicare budgets, incentivizing Congress to share the fiscal pain widely, perhaps with across-the-board budget cuts that would reduce funding for all research and other agencies.

The White House Office of Management and Budget, in fact, has asked agencies to submit fiscal year 2013 budget proposals that are at least five percentage points lower than their enacted 2011 levels. The agencies also were asked to identify an additional five percent in potential reductions from 2011 levels as part of the administration's budget deliberations.[6] If the research agencies examined above were to sustain annual budget cuts between five to ten percent, they would rapidly fall below the fiscal year 2007 levels that were widely acknowledged as inadequate to sustain American competitiveness.

International Trade in Arms Regulations (ITAR) Initiative

At TLSI Dialogue 1 in June of 2009, participants raised two broad concerns with the U.S. export control system, or ITAR. The first concern is that ITAR restrictions lag behind the pace of global technology diffusion, blocking U.S. firms from selling leading-edge technologies worldwide, even when that technology is available from other global sources.

The second concern is that ITAR rules overly restrict federal-supported research projects to which foreign students may contribute. Several TLSI participants noted that a greater pool of talent could be applied to defense-related challenges without compromising national security.

6 Lew, Jack. ***Memorandum for the Heads of Departments and Agencies (M-11-30)***. Office of Management and Budget. August 17, 2011. http://www.whitehouse.gov/omb/memoranda/2011/m11-30.pdf

In August 2010, President Obama announced an initiative to reform the U.S. export control system. According to the White House, "the initiative followed a year-long interagency review that determined that the current export control system is overly complicated and fragmented, contains too many redundancies, and, in trying to control too much, diminishes our ability to focus on the most critical national security priorities, impairs the interoperability of our Armed Forces with our allies in the field, and undermines the competitiveness of sectors key to U.S. national security."

The current system, explained the White House release, is based on two control lists administered by two different departments, three different primary licensing agencies (none of whom sees the others licenses), a multitude of enforcement agencies with overlapping and duplicative authorities, and a number of separate information technology systems. The fragmented system, combined with the extensive list of controlled items, dilutes the ability to adequately control and protect those key items and technologies that must be protected for national security. The goal of the reform effort is "to build high walls around a smaller yard" by focusing enforcement efforts on so-called "crown jewels."

The administration is pursuing a three-part implementation plan. Phase one establishes a framework for the new system and sets the table for any legislative changes. This phase establishes plans to: (a) streamline the control lists and set new criteria to screen future items onto the lists; (b) refine license regulations; (c) create an enforcement fusion center to synchronize actions; and (d) launch assessments of the information technology infrastructure and begin work on a single U.S. government point of entry for exporters.

Goals of President's ITAR Reform Initiative:

- Single Control List
- Single Primary Enforcement Coordination Agency
- Single Information Technology System
- Single Licensing Agency

Phase two actions include creating identical tiered structures for the control lists, adding or removing controls on certain items, and harmonizing license requirements for each tier. Congressional notification will be required to remove munitions list controls or transfer items from the munitions list to the dual-use list, and additional funding will be required for enhanced enforcement and IT infrastructure.

Phase three anticipates the transition to a new U.S. export control system. Legislation would be required for this phase, which would merge the control lists, create a single licensing agency, consolidate enforcement, and implement a single, enterprise-wide IT system.

Congressional Reaction: House of Representatives

The House Foreign Affairs Committee held an oversight hearing May 12, 2011, on export controls. Excerpts from Chairwoman Ileana Ros-Lehtinen's remarks:

Ultimately, new legislative authorities would be required to implement the administration's plan—a plan substantially at variance with the current statutory scheme for controlling defense articles under the Arms Export Control Act and dual-use items under the Export Administration Act…To date, a compelling case has not been made for the wholesale restructuring of our current system.

Although there are several aspects of the ongoing reforms that many of us do support …[w]e are particularly concerned that the pace and scope of the ongoing "list review"—which simultaneously includes: establishing a new "tiering" structure for controlled exports; a comprehensive review of the Munitions List; and a complete re-write of that list's 21 categories of defense items—is straining the system and its personnel to its breaking point.

…The administration should reconsider this time-consuming exercise and focus on common sense reforms upon which we can all agree. One example may be the treatment of generic parts and components—rivets, wire, bolts and the like—currently controlled on the Munitions List because they were designed for military use but which have little in the way of inherent military utility. Toward this end, I intend to introduce legislation to clarify that generic parts and components need not be regulated in the same manner as the more sensitive defense articles. This modest, but important, step would address a key concern of small- and medium-sized enterprises, larger defense firms, and our allies.

…These, and other legislative changes, together with our intent to authorize a short-term extension of the lapsed Export Administration Act, will help enable Congress and the administration to tackle together the critical changes necessary to strengthen our national security, while advancing commercial interests." Rep. Ros-Lehtinen introduced legislation June 3, 2011.

On July 19, 2011, the Commerce Department issued proposed rules to:

- Lay out the process by which less militarily significant items (e.g., parts and components) will be transferred from the U.S. Munitions List (USML) to the more flexible Commerce Control List within a new control series (informally termed the Commerce Munitions List);
- Define the licensing policies for those items that will be moved;
- Propose a single definition for a term "specially designed" to clarify a central element of the export control system; and
- Demonstrate the application of this process to one category of the USML Category VII (Tanks and Military Vehicles).

Comments were collected on the rules through September 13, 2011. The administration has made clear that no items will move to the Commerce Control List until the administration considers the public comments received on the proposed rule and consults with Congress.

Lab to Market Initiatives

At the September 16, 2011, signing of the America Invents Act, President Obama also announced initiatives designed to boost public-private collaboration and speed the transition of technologies from lab to market. In concert with the White House announcement, more than 40 universities issued their plans to bolster commercialization.[7]

Although the initiatives do not consist of big-budget or major policy shifts, they encourage greater cooperation across federal agencies, universities, companies and technology priorities. The initiatives will:[8]

- Invest $70 million each by the National Institutes of Health (NIH) and the Defense Advanced Research Projects Agency (DARPA) to develop a chip able to quickly screen drugs for toxicity and effectiveness. The Food and Drug Administration (FDA) also will partner on this initiative.
- Decrease the cost and paperwork for start-up companies to license technologies that are patented by NIH and FDA intramural researchers. Start-ups must be less than five years old and have fewer than 50 employees.
- Create a pilot program sponsored by the USPTO, the NSF and the Small Business Administration to offer pro bono or low cost intellectual property support to 100 Small Business Innovation Research (SBIR) grant recipients.
- Establish a $400,000 program to award prizes for exemplary university commercialization activities. The NSF will partner with the Wallace Coulter Foundation and the American Association for the Advancement of Science to fund and administer the program.
- Engage the administration in support of an effort by 135 universities to boost entrepreneurship, commercialization and corporate engagement. The effort is coordinated by the Association of American Universities and the Association of Public and Land Grant Universities.

7 Kalil, Tom and Maynard, Rick. ***America's Universities Growing the Economy With "Lab to Market" Initiatives***. The White House Blog. September 28, 2011. http://m.whitehouse.gov/blog/2011/09/28/americas-universities-growing-economy-lab-market-initiatives

8 Erickson, Britt and Morrissey, Susan. ***President Obama Announces Several Initiatives to Encourage, Support Commercialization***. Chemical & Engineering News. American Chemical Society. September 19, 2011 http://pubs.acs.org/cen/news/89/i39/8939_20110919np2.html

- Issue an administration "Bioeconomy Blueprint," to harness biological research to address health, food, energy and environmental challenges

Startup America Recommendations

The president also launched Startup America in January 2011 to promote entrepreneurship. The initiative includes a partnership with the private sector. Following the White House initiative, private sector leaders created the Startup America Partnership, an independent alliance chaired by AOL founder Steve Case and a board of prominent entrepreneurs.

Case called recently for a series of reforms,[9] such as:

- Removing regulatory burdens under the Fair Disclosure Act and other laws that hinder small businesses from launching initial public offerings
- Reforming immigration laws to retain highly skilled foreign students educated at U.S. universities.
- Expanding seed investment and angel capital available to startups through federal incentives
- Easing the process to acquire Small Business Administration loans
- Improving the patent process by hiring a dedicated USPTO team to work with small companies and to allow an expedited review of "in market" patents

9 Harrison, JD. *Startup America Looks to Washington.* Portfolio.com. October 7, 2011.

PART 1: SETTING THE STAGE FOR TLSI DIALOGUE 6

Recommendations of the TLSI Working Groups

In the reports preceding the TLSI Dialogues 4 and 5, the Council shared information about the priorities of the TLSI Working Groups, including a chart that summarizes the objectives of the groups (figure 7). In each of these objectives, the working groups are finalizing more detailed and actionable recommendations. The Accelerating Innovation Working Group, for example, has set an objective to build communities of innovation and entrepreneurship. To achieve that objective, the group recommends:

- Facilitating access to labs and universities to engage potential partners and make information on research projects more widely available;
- Coordinating federal funding streams to innovation hubs that center on a particular set of challenges and condition hub location on funding and policy support by state and local governments;
- Establishing formal procedures for lab and university employees that ease their ability to establish firms and transition to the private sector; and
- Enhancing the missions and incentives at national labs to encourage commercialization in partnership (not competition) with industry.

Similarly, the Regulation-Policy Working Group will consider the status and substance of ITAR reform and communicate specific priorities. The Talent Working Group is examining best practices in community colleges that help drive innovation, including their relationships with local industry, national labs, economic development organizations and other universities.

As the TLSI prepares to issue final recommendations and shift to implementation mode, the work of the Innovation Outreach Working Group will play a strategic role. The Council intends to cull ideas at TLSI Dialogue 6, October 24, 2011, to promote and implement the recommendations. Outreach activities could include regional events, media engagement, and interacting with federal, state and local policymakers. To be truly successful, the Council should partner strategically with like-minded organizations, develop effective messaging and establish metrics of success to benchmark progress.

Figure 8 offers a partial snapshot of the types of engagement needed just at the federal policy level for the objectives of the Regulation-Policy Working Group. The table is kept simple to be illustrative, but in reality the universe of engagement is typically larger, including Congressional leadership, appropriators and officials within the Executive Office of the President (e.g. Office of Science and Technology Policy, Office of Management and Budget).

Coordination with Council's U.S. Manufacturing Competitiveness Initiative (USMCI)

As part of an implementation strategy, Council members should bear in mind the integration between the TLSI and USMCI. By serving as the technology think tank for USMCI, the TLSI gains a wider audience for its ideas and additional opportunities to share them. The USMCI also is preparing recommendations that will be unveiled in December 2011.

Figure 7. Objectives Pursued by TLSI Working Groups

Accelerating Innovation

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

Regulation / Policy

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

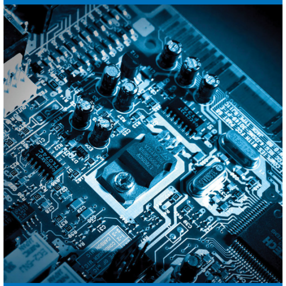
Talent

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

Innovation Outreach

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

High Performance Computing



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

TLSI Working Groups

Figure 8. Sample Federal Government Engagement Matrix

Objective	Lead Agencies	Lead House Committees	Lead Senate Committees
Reform ITAR rules	State, Commerce & Defense departments	Foreign Affairs	Foreign Relations
Maintain federal support for basic research	NSF, NIH, NASA, plus Energy, Defense & Commerce departments	Science, Space & Technology Appropriations	Commerce, Science & Transportation Appropriations
Retain highly skilled immigrants trained in United States	Homeland Security, Commerce & Education departments	Judiciary	Judiciary
Streamline and modernize the patent process	USPTO (Commerce)	Judiciary	Judiciary
Remove conflicting regulations impacting research enterprise	NSF, NIH, IRS, NASA, plus State, Commerce, Defense & Energy departments	Science, Space & Technology Ways & Means	Commerce, Science & Transportation Finance
Update and enhance the R&D tax credit	Treasury Department	Ways & Means	Finance

Part 2:
Findings From
TLSI Dialogue 6

PART 2: FINDINGS FROM TLSI DIALOGUE 6

Opening Remarks

Deborah L. Wince-Smith, president & CEO of the Council on Competitiveness, welcomed participants to the sixth dialogue of the Technology Leadership and Strategy Initiative (TLSI).

She thanked the TLSI co-chairs: Klaus Hoehn, vice president for advanced technology and engineering at Deere & Company, Ray Johnson, senior vice president and chief technology officer of the Lockheed Martin Corporation, and Mark Little, senior vice president and chief technology officer of the General Electric Company. She also thanked Vice Admiral Michael Miller, Superintendent of the United States Naval Academy, and Andrew Phillips, academic dean and provost of the United States Naval Academy, for hosting the dialogue and a reception the prior evening.

Deborah L. Wince-Smith, Council on Competitiveness, and Klaus Hoehn, Deere & Company.

Wince-Smith stated that the United States faces tremendous economic and security challenges. “While technological innovation and investment is not a panacea,” she said, “the Council on Competitiveness believes that America’s innovation capacity and the ability produce new products and services are important pathways to our future.” She explained that technological innovation is linked to manufacturing and that TLSI recommendations will be integrated into the Council’s U.S. Manufacturing Competitiveness Initiative (USMCI).

Little praised the work of the TLSI and emphasized the importance of moving from forming recommendations to implementing them. Hoehn added that moving forward will require greater collaboration between the Council’s TLSI and USMCI—that collaboration presents an opportunity to bring more stakeholders together to put forth a more powerful message. Hoehn also advocated a closer working relationship between industry and the national laboratories. “We struggle sometimes to leverage each other,” he noted.

Jason Moore and Ray Johnson, Lockheed Martin Corporation, and Michael Miller, United States Naval Academy.

Johnson highlighted three issues of global competitiveness. First, he noted a "technology leveling" effect, where technologies not only diffuse quickly across the globe, but also that leading technologies are less likely to originate in the United States than they did in the past. Second, Johnson observed that the global economy is changing the types of jobs available for middle class workers, and that debt-leveraged developed countries are struggling to address that change.

Finally, Johnson acknowledged America's continuing struggle, including cultural issues, to educate sufficient numbers of students in science, technology, engineering and mathematics (STEM) disciplines. He closed by noting the Council agendas focused on technology, energy, high performance computing and manufacturing, and called for their implementation. "We need to make sure that we address these issues."

PART 2: FINDINGS FROM TLSI DIALOGUE 6

Research at the U.S. Navy and Defense Department—Foundations and Future

Rear Admiral Nevin Carr, Jr.
Chief of Naval Research
Director, Test and Evaluation and Technology Requirements
United States Navy

Thank you, Deborah, for inviting me to come here. One of the things that I'm responsible for is the Navy STEM outreach effort. We face an aging technical work force in the Navy, civilian more so than military, and primarily in our labs. We are looking to connect our demand with supply, because supply is not keeping up with demand in this country for STEM education. Like all the services, we are working closely with the Office of the Secretary of Defense and Dr. Laura Adolfie to collaborate and coordinate our outreach efforts on STEM.

I will discuss some top level education statistics that tell a story of the three million high school graduates in this country. We are approaching the layers of this cake (Figure 9) in different ways. Down at the bottom level, you want to inspire kids, try and get them interested and give them the academic confidence that they need to take those hard subjects in high school and college so they feel like they can succeed. Of the three million high school graduates, only two million go to college at all. Roughly half of those students—about 980,000—begin a major in a technical discipline, but only about 480,000 actually graduate with a STEM degree. That's a 50 percent cut and a mentoring issue. So there are different ways of attacking the levels of this pyramid.

The numbers continue to decrease in graduate school. According to the National Science Foundation, we crossed a line in this country two years ago and

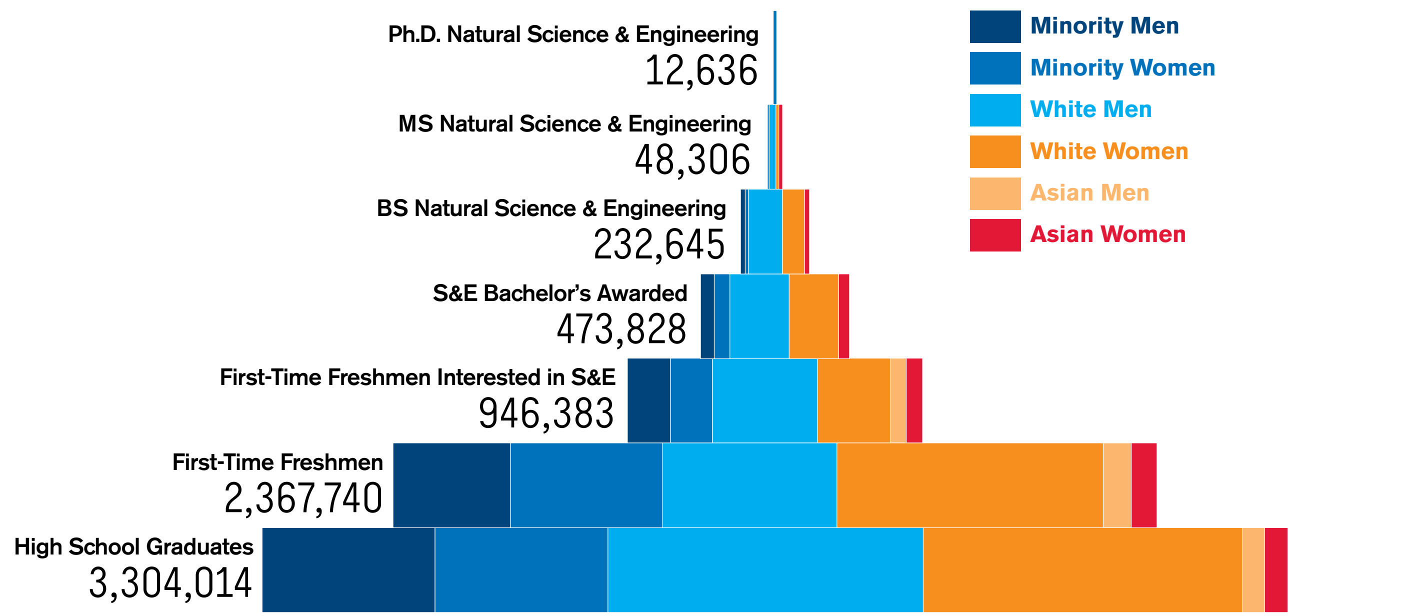
Chad Evans, Council on Competitiveness, and Nevin Carr, Office of Naval Research.

began awarding more advanced degrees in STEM education to non-U.S. citizens than to U.S. citizens. As you all know so well, immigrants made our country great. Traditionally, people came here, took advantage of our educational institutions and then stayed. Now, however, they are staying in smaller numbers and, in many cases, they are going back home to work for U.S. companies that have relocated overseas.

Traditionally, the Navy has allocated $54 million for STEM education. Recognizing the growing importance of STEM, Secretary of the Navy Ray Mabus has directed me to double that amount, and we have begun a path to reach that goal. The current distribution of funds resembles a slope (Figure 10), with a majority of the funds in the middle designated for secondary education ($40.1 million). On the ends, funds are directed toward growing employment for the STEM graduates ($17.2 million) and for growing interest in STEM studies in K-12 ($17.1 million).

Figure 9. Degrees Awarded to U.S. Citizens and Permanent Residents

Sources: National Science Foundation, *Science & Engineering Indicators*, 2010; National Center for Education Statistics.



Notes: Minority includes Black/African American, Hispanic and Native American. White does not includes Hispanic. Asian includes Pacific Islander. Natural sciences include physical, biological, Earth, atmospheric, ocean, agricultural, and computer science and mathematics.

Figure 10. Distribution of Navy STEM Outreach

STEM2Stern, Office of Naval Research

	$17.6 M			$40.1 M ↑			$17.2 M
	Elementary	Middle	High School	Undergraduate	Masters	Ph.D.	Faculty Research, Teacher Training and Professional Development
PROGRAMS	Girls Only		Internships	Internships	Internships	Scholarships	Young Investigator
	Family Science		Robotics	Scholarships	Scholarships	Fellowships	Summer Faculty
	Science Fairs		Camps	Competitions	Fellowships		
	iApps		Competitions	Co-ops			

An exciting undertaking focused on the beginning end is being developed with the Defense Advanced Research Projects Agency (DARPA). The project centers on intelligent tutoring. Using computer based training and artificial intelligence, we learn from the student who is undergoing the training—what they know and don't know—and shape the training for them. We have demonstrated in trials pretty significant increases in what students can learn without a person present to tutor them. A machine can almost tutor them as well as a person in some cases. We have used it within the Navy in some of our training and educational courses, and there is some excitement about how this might apply to high school students, for example, with SAT preparation.

If you would like to learn more about what the Navy is doing to promote STEM education, I urge you to search online for our "STEM 2 Stern" pamphlet that outlines our activities in greater detail. I'd also like to say that I am a big believer in the Naval Academy's STEM efforts, particularly its cyber curriculum that helps jump start students as they enter the services. I spoke at the Academy recently on the subject of emerging technologies, because some of the innovations the Navy is testing now are going to become the systems, weapons and tools that Academy graduates will use in the near future—such as directed energy weapons, faster drying paint and everything in between. I want to thank you for the opportunity to come and talk to the TLSI. Thanks for what you are doing for our global competitiveness.

Dr. Andrew Phillips
Academic Dean and Provost
United States Naval Academy

A lot of the remarks made this morning are a terrific foundation to what I would like to talk about. The Naval Academy, now 166 years old, has always been about meeting challenges—about adapting and innovating to changing requirements and times. I know there are a number of you in the room who are Naval Academy graduates. You probably recognize from the time when you were a midshipman that the Naval Academy has continually evolved to meet challenges, whether they're in science, engineering, computing—or perhaps most recently—in languages, cultures and cyber fields.

Andrew Phillips, United States Naval Academy.

The mission of the Naval Academy is to graduate leaders for the Navy and the Marine Corps. But at a deeper level, it's really about leadership to meet challenges wherever the graduates find themselves in life—including government or in business and industry. Here is an individual that some of you may know personally (presented a picture of Admiral Michael Mullen, former Chairman of Joint Chiefs of Staff, as a midshipman between 1964 and 1968). When he was here, he faced an uncertain future. It involved Vietnam, the Soviet Union, a race into space and the beginnings of digital computing. His Academy education was a fixed curriculum. He had no options other than what he studied for a language. He studied Italian. But his fixed curriculum, what we call the lock step program, provided him a very strong foundation in science and engineering.

Admiral Mullen just finished his 43rd year in leadership of the most powerful military of the most powerful nation on earth. What he learned as a Naval Academy midshipman served him for 43 years in those kinds of leadership posts. When he was a midshipman back in the late '60s, the first ballistic missile submarines were just going to sea and the first satellites were being launched to populate the upper atmosphere. He didn't know that he would need to adapt and innovate in countries that he hardly knew existed—with technologies yet to be invented. Our task at the Naval Academy is to educate people like that. Someone in the brigade of midshipmen today is likely to be the Chief of Naval Operations or perhaps the Chairman of the Joint Chiefs in 40 years. Our challenge is to always understand that we will need people to lead this nation 40 years out and to provide them foundations in science and engineering so that they can make a difference and lead our country in that future era.

I fear our challenge has become a little bit more difficult lately. Before I get to that I want you to take a look at this (Figure 11). One way to look at leadership just in the Navy is that of the 221 flag officers who lead in the Navy today, 55 percent of them are Naval Academy graduates. Only 30 percent of the brand new officers each year, however, come from the Naval Academy. So the Academy produces about one third of the officer corps, but 55 percent of the flag officers. More to the point, if you look at the senior levels at the three and the four star ranks, the leadership is much more tilted toward those who graduate from Annapolis. In fact, eight of the ten most senior admirals are Academy grads, and that's typical of most years. The point may be a little more subtle though. Leadership in the Navy, similar to the Army and Air Force, is cultivated over many years—20 to 40 typically—starting either at the Academy or a Reserve Officer Training Corp program. There is no such thing as

Figure 11. U.S. Navy Active Duty Flag Officers
As of October 1, 2011

Rank		Number	USNA Grads
★★★★	Admiral	10	8 (80%)
★★★	Vice Admiral	32	22 (69%)
★★	Rear Admiral	55	29 (53%)
★★	Rear Admiral (Sel)	19	11 (58%)
★	Rear Admiral	73	37 (51%)
★	Rear Admiral (Sel)	32	14 (44%)
	Total	**221**	**121 (55%)**

a lateral transfer into this list from academia or from business or industry. To lead the nation's Navy, Marine Corps, Army or Air Force, you start as an ensign, and we grow our own through the program. So while these folks may end up leading in other areas later in life, the Navy is special in regard to how leadership comes from the bottom and up through the ranks. We are to blame if it doesn't work, because it is developed here.

Our history is full of Naval officers who have made significant contributions to innovation in science and engineering, both during or after their active duty time: (1) Albert Michaelson, one of our early Academy faculty members and a Nobel Prize winner for his measurements on the speed of light, (2) Matthew Maury, the father of modern oceanography and a Naval officer and scientist, and (3) Stanford Hoover, a rear admiral and Naval Academy graduate who can lay claim as the father of modern radio. Hoover started out as a midshipman, later taught here in physics and in chemistry, and then led the Navy's radio division. The list also includes Hyman Rickover, the father of nuclear power, serving at a time that demanded a revolutionary change in energy technology in the arms race of the cold war. Another Naval Academy graduate ended up leading an especially important office, President Jimmy Carter.

Here's my point, the Navy has always been challenged to innovate in science and engineering. Rickover's accomplishments are so well known that they hardly require additional discussion, but in Naval aviation we've also evolved considerably and continue to do so. Some of the first aircraft were tested right here. We rolled them out of Dahlgren Hall and took them off up over the river, so they were first tested here. Those tests would almost kill a young Lieutenant John Towers. Thankfully, Towers survived and rose to four stars and to command the Pacific Fleet after building the air fleet that would defeat the Japanese in World War II.

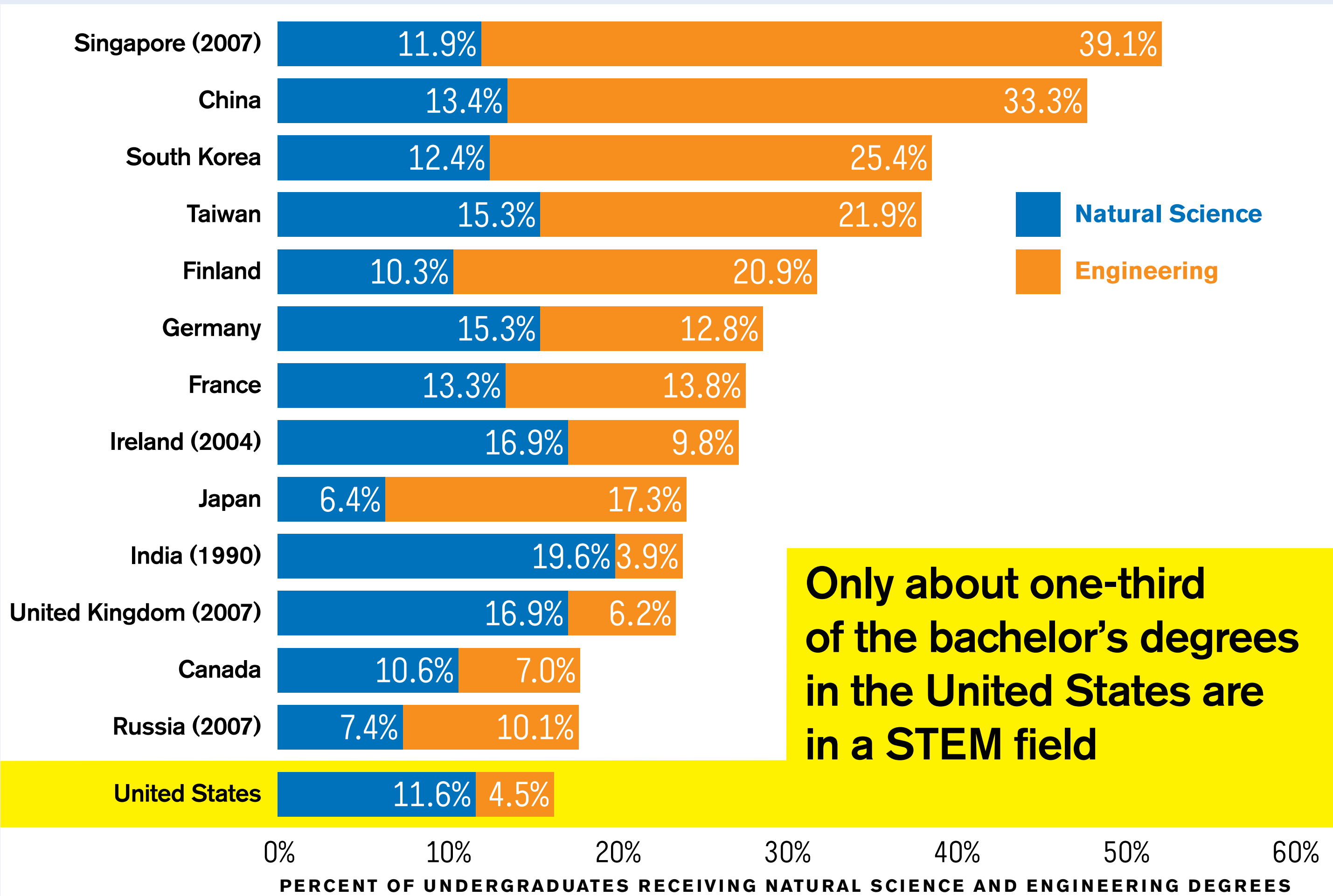
Moving forward, we will be looking toward unmanned aerial vehicles (UAVs) like the prototype X-47-B (Figure 12), a stealth aircraft that only a few years ago would be hard to imagine. Several members of our current faculty are international experts in this field. They build on a legacy of scientific leaders such as Grace Hopper, a Navy admiral who was an early technical expert in computing, and Gary Kildall, a Navy lieutenant who wrote the DOS operating system while assigned at the Navy's postgraduate school. Robotics devices and of course UAVs are now mainstream technologies that continue to proliferate in the military. The Naval Tactical Data System was the first solid state mobile network and was built and managed by several Academy graduates in the 1950s. Today, we are focused on what Vice Admiral Arthur Cebrowski called network centric warfare, one of our biggest technical challenges.

Figure 12. Navy X-47-B Unmanned Aerial Vehicle

What lies ahead is uncertain, and we must prepare our next round of leaders to innovate and adapt to whatever the future presents. Intellect, knowledge and innovation are the weapons needed to win wars and to operate our complex systems. Let me ask how the nation's doing as far as preparing our future leaders in all areas, not simply within the Navy and STEM fields, but in a manner necessary to adapt and innovate? Admiral Carr alluded to this challenge in his remarks.

In the United States, STEM fields have been critical to generating new ideas; companies and industries that have driven our economic competitiveness. The importance of STEM will only grow in the future. According to a recent report from the Department of Commerce, STEM occupations are projected to grow by 17 percent in the next eight years, compared to just under ten percent growth for non-STEM occupations. According to the Organization for Economic Cooperation and Development, the United States ranked 27th out of 29 developing countries in 2009 in the percentage of students who earned bachelor's degrees in science and engineering. America produces only 16 percent of its gradu-

Figure 13. Is the US Competing in STEM?
Source: NSF Science & Engineering Indicators

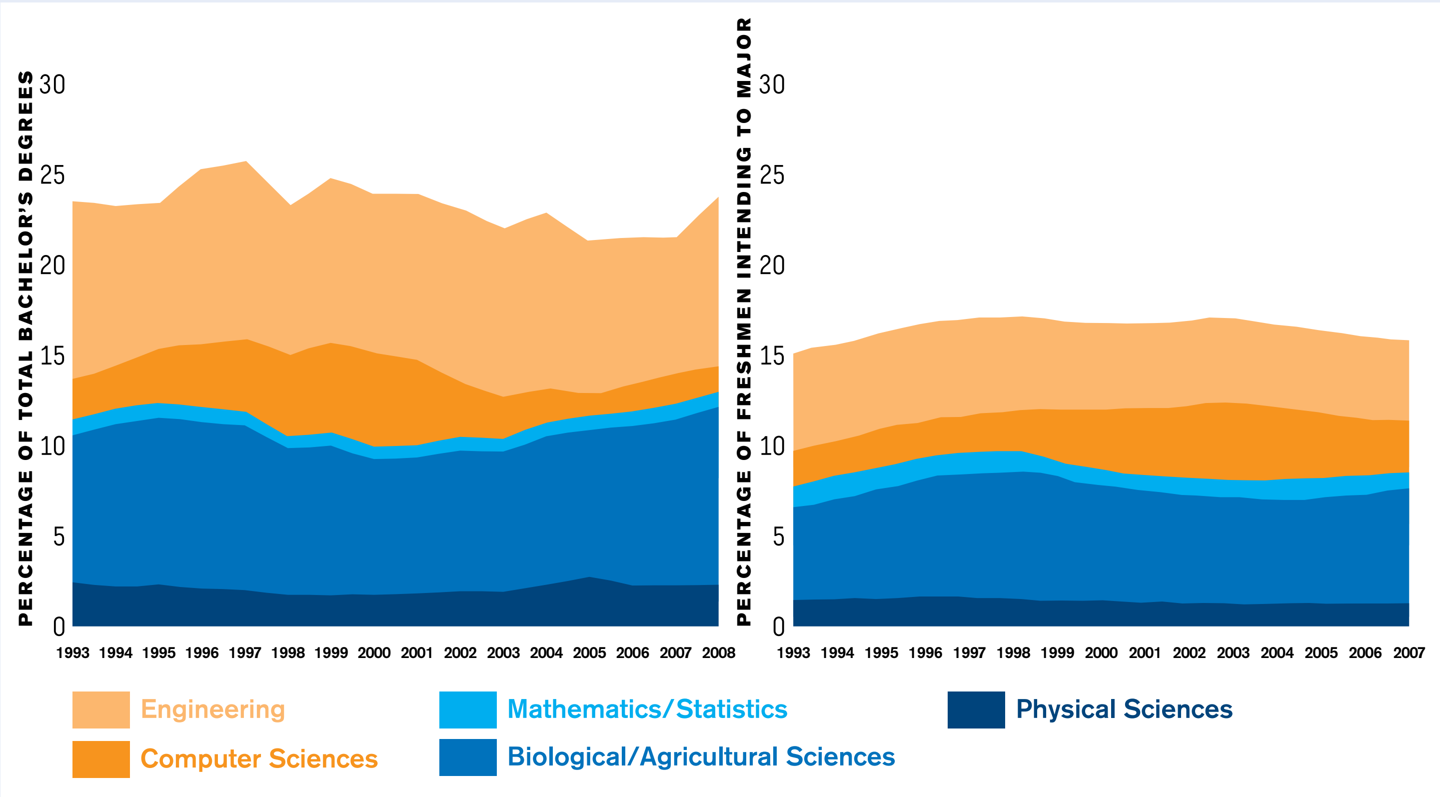


ates in science and engineering. Even when you add mathematics and technology, the United States continues to lag (Figure 13). Only about one-third of the bachelor's degrees in the United States are in a STEM field, compared to approximately 53 percent in China and 63 percent of those earned in Japan. Additionally, more than half of the science and engineering graduate students in the United States are from outside the country.

According to the National Science Foundation (NSF), U.S. university enrollment and graduation continues to increase in both STEM and non-STEM fields. However, STEM degrees as a proportion of the total number of bachelor's degrees have remained relatively constant between 15 and 17 percent. There is very little growth in engineering, math and the physical sciences. The STEM fields with growth are narrowly limited to computer science and the biological and agricultural sciences. Why is that? What can explain that?

Let's look at what entering students say about what they think they want to do when they go to college and compare that to what they actually end up studying (Figure 14). The proportion of freshmen intending to major in STEM fields has been relatively constant at just below 25 percent for the past 15

Figure 14. Freshman Intent vs. Graduates in STEM
Source: NSF S&E Indicators 2010, Appendix Tables 2-6 and 2-12.



years. However, the data shows engineering numbers declining. The gap between the percentage of freshmen who intend to major in STEM fields and the percent actually awarded bachelor's degrees in those fields is a persistent trend.

The greatest declines occur in engineering and physical and biological sciences. In fact, many students who intend to major in the STEM fields do not complete their degrees, or they end up earning a non-STEM degree. According to a 2005 survey of American freshmen, 50 percent of students who begin in the physical or biological sciences, and 60 percent of those in math, drop out of those fields by their senior year, compared to only 30 percent who drop out in the humanities and social sciences. Why do so many students who enter college saying they want to pursue a STEM degree end up not doing so? Several studies show that most students who leave STEM fields do so between the first and second year of college.

There is a famous survey of students that shows that 90 percent of students who switched out of a STEM field cited poor teaching as the reason for doing so. Additionally, 73 percent of those students who earned a degree in STEM also cited poor teaching in science and engineering. So poor teaching is clearly part of the problem in keeping people in STEM fields. Half of the students who left STEM also cited the curriculum as over loaded, the pace too fast and overwhelming, and non-STEM majors as more interesting than STEM majors. Of the 23 most commonly cited reasons for switching out of STEM, all but seven have something to do with the pedagogical experience students had. Poor undergraduate teaching is a major factor in students choosing to leave STEM fields, and because most students who leave STEM do so in the first two years of college, those years are especially critical to stemming the tide of students leaving STEM.

The problem is not concentrated only in secondary education, but spans back to K-12 education where recent reports claim that less than one-third of U.S. eighth graders show proficiency in math and science, and that test scores have improved very little over the past few decades. According to a recent international survey, the United States no longer ranks in the top ten in science or math literacy among 15-years-olds worldwide. The United States is ranked 21st in science literacy among the survey's 30 participating countries that are the wealthiest and most technologically advanced nations in the world. The United States fares even worse in math literacy, ranking 25th. Somewhere between the fourth grade and high school, American students fall behind in math and science. U.S. students hold their own against their international counterparts in the fourth grade, but then they begin to fall behind. Fewer than 15 percent of high school graduates have enough math or science to pursue a science or technical degree in college, and less than two percent of U.S. high school graduates will earn an engineering degree. Europe produces three times as many engineering graduates as the United States each year, and Asia five times as many. Female students only make up 17 percent of the engineering enrollments at U.S. colleges and universities. African American and Hispanic students represent less than 14 percent of engineering enrollments nationwide.

While American interest in the science and engineering fields is declining, the rest of the world is advancing. The Naval Academy is swimming vigorously against those trends, pushing science and engineering back to the forefront. Our goal is for at least 65 percent of our annual graduates to major in a STEM field. Approximately half of every graduate's curriculum will consist of science and engineering coursework, even if that's not what they major in. So every Naval Academy students gets a Bachelor of Science degree, and there are 50 credit hours dedicated to science and engineering. Those are significant goals, expectations and challenges for us. You can't meet those goals with passive and traditional educational approaches. I think the data I've shown shows that to be a fact. It takes active effort to get 65 percent of your graduates in science and engineering, and you have to have that active effort early, and you have to do it often throughout the academic program.

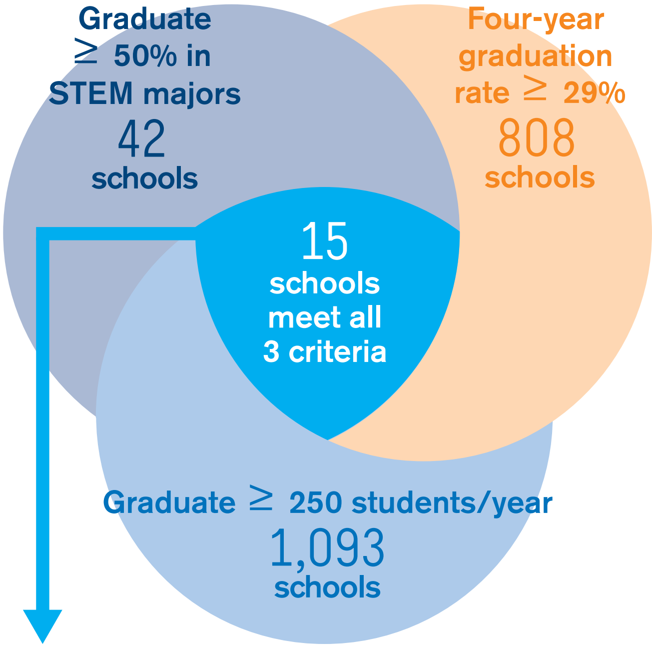
Is it hard to make STEM exciting enough for students to initially pick it, and exciting and engaging enough for them to stick with it until graduation? Is it hard to even make a majority of students study STEM and complete their degrees in four years? The answer to those questions is yes, it is hard to do that.

This chart (Figure 15) shows you how hard. It presents a sample of all colleges and universities in the nation that are Carnegie classified doctoral, masters or bachelors programs that you would reasonably expect to have science and engineering programs. If you ask how many of those universities graduate at least half of their students in a STEM field, the answer is that there are only 42 in the nation. If you ask how many universities have four year graduation rates that exceed the national average of 29 percent, only 808 schools do that. If you ask how many schools graduate at least 250 students per year, there are a little over a thousand.

At the intersection of all three points, the number of universities in this country—Carnegie classified—that have at least 250 graduates, a four-year graduation rate that is at least as good as the national average and half of their graduates study STEM, there are only 15 institutions. This matrix produces a pretty

Figure 15. Efficient Production of STEM Graduates

Sources: The Education Trust, 2009 Data



TOP 8 BY 4-YEAR GRADUATION PERCENTAGE RATE

1. USNA 88.2%
2. MIT 82.7%
3. Rose-Hulman 68.9%
4. Worcester Poly 67.5%
5. Carnegie Mellon 67.5%
6. Rensselaer Poly 63.8%
7. Case Western 63.2%
8. Clarkson 51.7%

spectacular list of schools, and gives you a sense of how hard it is to achieve these objectives and the kinds of schools that you must be. You might notice that the schools are generally STEM-focused colleges and universities with a reputation in these fields.

How does the Naval Academy accomplish this? I suppose we have a built in advantage in that every student who comes here knows to expect balance in the program between the moral and leadership part, the academic part, and the physical and athletic part. It is understood and expected, even desired, by every midshipman who enrolls. In fact, when I ask the midshipman about their interests, I ask them how many of them chose the Naval Academy because it was the easiest of their options of universities to attend. No one ever says that was the reason. They already know it will be challenging—that's the point. So there is a built in self-sense of well roundedness at the Naval Academy. The midshipmen know that we will challenge them intellectually. We pride ourselves on keeping our programs on the cutting edge in STEM. Our facilities are top notch, and we do everything we can to provide opportunities for midshipmen to use those facilities and be challenged to excel. We hire the best faculty that we can find—most are recent graduates from Ivy League schools or of peers of Ivy League schools. We put students together with faculty as often as we can in small settings. Average class sizes at the Naval Academy are 19, and there are no classes over 35. We highly value face to face interaction, and great teaching is the rule at the Naval Academy. Our faculty knows that the education of midshipmen is job No. 1, and that outstanding teaching is the norm. No amount of other ability in any other area would overcome our expectation for outstanding teaching. So if a midshipman were to say that the classroom experience was degrading their interest in science and engineering, that would be a big problem for us, and we would take that quite personally.

We place a great emphasis on active and project based learning. We believe the best way to educate midshipmen for the future is to get them involved in hands on activities that will keep them engaged in their majors. We educate them for a career, develop them to serve in a technical world with the ability to adapt and innovate in changing circumstances. The best way to do that is to immerse them in science and engineering activities because that will help them in 30 years. This model is proving to be successful for us, and the statistics I showed you bear that out. This is how we are able to produce the Mike Mullens of the future. That person will need an education steeped in STEM development now and relevant in the future.

I hope my focus on the Naval Academy, its history and what we're doing, and our connection to innovation is going to be helpful to you. When you see some of the facilities a little later today, you might make some connections between the pictures I've shown and what we're actually doing. The tours we will have will be led by midshipmen, and I encourage you to ask them about their experience in science and engineering and see what they have to say. I appreciate and thank you all for coming to the Naval Academy for this event. We consider this a great honor to be able to host you here and to show you what we're doing on this important topic and allow you to see for yourselves how your tax dollars are being used to help educate the leaders for the future. Thank you very much.

Mark Little, General Electric Company, and Ray Johnson, Lockheed Martin Corporation.

Discussion

Johnson thanked Carr and Phillips and shared their concern with the state of STEM education in the United States. Johnson also added that "when we think about academics here at the Academy, it is important to realize that the kind of warfare that the students here will face as naval officers is going to be very different. We are going to see a lot of different kinds of weapons technology in which nations besides the United States are making big investments. A lot of those weapons will show up in an asymmetric way and the global nuclear and conventional protective umbrella of the United States won't be as effective against some of those different kinds of weapons."

Chad Evans, Senior Vice President at the Council on Competitiveness, introduced the midshipmen who would take the TLSI participants on tours of Naval Academy research projects and facilities. The tour groups learned about: (1) nano electronics and atomic works microscopy, (2) atmospheric processes and tropical cyclone, (3) biometrics research and application design, and (4) piston engine crankshaft and advanced deposit material research.

PART 2: FINDINGS FROM TLSI DIALOGUE 6

Luncheon Remarks

Rachel Goslins, executive director of the President's Committee on the Arts and Humanities, addressed the TLSI participants about the importance of arts education in overall student performance, particularly in STEM disciplines. She noted linkages between creativity and innovation, and encouraged TLSI participants to consider the findings and recommendations of her committee's report *Reinvesting in Arts Education: Winning America's Future Through Creative Schools*.

Goslins invited TLSI participants to partner with her in efforts to promote the value of arts education and to preserve it in many schools around the country where it is disappearing or being cut back. The President's Committee also is striving to advance the field of arts integration, expand in-school opportunities for teaching artists and gather additional evidence about arts education.

"The United States has a long proud history of innovation and creativity," the *Reinvesting in Arts* report states. "This is one of our greatest assets and what will give our workforce an edge in an increasingly competitive global economy. But to do this, we need to prepare the next generation of inventors, designers and creators. Business leaders are already asking for this. They recognize that this is essential for our schools to be teaching children how to think outside the box and to address challenges with creative solutions."

Goslins shared research findings that arts education has great potential to bolster student engagement and achievement. She emphasized the importance of arts integration, where subjects such as math and science are integrated with arts disciplines. Such studies, Goslins said, find that low income kids who participate in arts education are four times more likely to have high academic achievement and three times more likely to have high attendance, and that those students are more likely to participate in a math or science fair.

Rachel Goslins, President's Committee on the Arts and Humanities.

Updates to the studies that tracked the same kids into their mid-twenties showed that the advantages increased over time. Arts-engaged low-income students are more likely to attend and do well in college, build careers, volunteer in their communities and vote. On average, arts-engaged low-income students tend to perform more like higher-income students in the many types of comparisons that the studies track.

Goslins also shared neuroscience findings that are shedding light on how the arts may influence cognitive development. The findings include:

- Music training is correlates closely with developing phonological awareness—one of the most important predictors of early reading skills.
- Children who practice a specific art form develop improved attention skills and improved general intelligence.
- Arts Integration techniques, which use multiple senses to repeat information, cause more information to be stored in long-term—as opposed to short-term—memory, and may change the structure of neurons.

PART 2: FINDINGS FROM TLSI DIALOGUE 6

Reporting Out and Framing Next Steps: TLSI Working Group Recommendations

Hoehn introduced the three TLSI Working Group chairs in attendance—Steve Ashby, deputy director for science and technology at Pacific Northwest National Laboratory; Mel Bernstein, senior vice provost for research and graduate education at Northeastern University; and Paul Hallacher, director of research program development at Pennsylvania State University. (Pradeep Khosla, dean of the College of Engineering at Carnegie Mellon University and chair of the Regulation and Policy Working Group, was unable to attend.)

Ashby, chair of the Accelerating Innovation Working Group, explained that the group developed five broad objectives designed to accelerate innovation and improve the nation's competitiveness. Ashby noted that within each objective, the group developed three to five actionable recommendations to achieve the desired outcome.

Brad Spiers, Bank of America, and Steve Ashby, Pacific Northwest National Laboratory.

The first objective, Ashby said, is "to form and leverage teams across various sectors—from industry, academia, the laboratories—and to achieve clearly articulated innovation outcomes." The outcomes should be of sufficient scale to address societal problems facing the nation, he stated. Ashby briefly reviewed the supporting recommendations to achieve the objective, such as structuring government sponsored competitions to encourage public-private partnerships. He noted that the U.S. Department of Energy (DOE) hub competitions were good examples.

The second objective is "to build communities of commercialization and entrepreneurship." Ashby reminded participants that a recurring issue for industry in previous TLSI dialogues is the difficulty of interacting with the national labs. As a result, several of the recommendations are designed to enable and incentivize engagements between national labs, universities and industry.

The group's third objective, Ashby said, is "to facilitate greater sharing of intellectual capital." An important recommendation tied to this objective is to ease restrictions on labs and universities so they may share their intellectual property (IP), including the bundling of IP generated by consortia. "When looking at the incentive mechanisms we use, people often are awarded simply for the number of licenses they produce, as opposed to making sure they have a path for getting the idea out into the market," Ashby said. "As a result we don't know how many licenses sit as opposed to actually getting the technology out and into use."

The fourth objective is "to create an innovation-friendly policy environment." Ashby noted that within this objective are several recommendations the Council has advocated for in the past, such as making the R&D tax credit permanent, reforming Sarbanes-Oxley and establishing a common set of innovation metrics. The fifth and final objective is "to bridge gaps in the innovation-to-marketplace pipeline." Ashby explained "there are two gaps, the one that goes from invention to tech maturation to develop the prototype, and another of moving the technology out of the laboratory and commercializing/producing at scale in the market place."

Ashby pointed out that there are relationships and interplay between the five objectives. For example, the third objective encourages labs to work with industry on commercial terms, including timely contract negotiations with performance guarantees. That recommendation dovetails with those from the second objective to build communities of commercialization and entrepreneurship. The DOE, Ashby said, is working on a proposal to facilitate access to labs and resources through new policies.

Bernstein, chair of the Talent Working Group, pointed out that discussions about talent tend to focus only on STEM education and that although STEM is an issue of great importance, the group felt challenged to think of recommendations that are important but receive less attention. In doing so, the group decided to frame its recommendations around the idea of building talent needed for competitiveness. Bernstein observed that from an employment standpoint, the United States is no longer primarily a manufacturing nation. The nation, however, cannot survive solely on the service industry. Bernstein explained how Council initiatives in manufacturing and high performance computing led the working group to focus in part on how to educate and train for modern manufacturing.

A primary focus of the working group is on community colleges, Bernstein said. Community colleges are not only a pathway to an associate's degree and a four-year institution, he said. Community colleges

Mel Bernstein, Northeastern University.

have great potential to collaborate with industry and universities to re-train and confer 21st century skills to the workforce. The working group has conferred with the American Association of Community Colleges (AACC) and found common interests.

President Barack Obama has identified community colleges as a critical element in revitalizing the nation's competitiveness, Bernstein added, and the federal government is putting together training resources for that purpose. The AACC is also preparing a study to be released in the spring of 2012 with recommendations on how community colleges can take action and be leveraged more effectively. "We believe that there is a real opportunity here to collaborate; to really be able to link our interest and our activity around competitiveness with this large network of institutions that has populations of younger people looking to be prepared, but also more mature workers seeking re-training," Bernstein said.

Paul Hallacher, chair of the Innovation Outreach Working Group, introduced three perspectives that frame the group's mission. "First would be policy advocacy," he said. "How do we reach out to policymakers in Congress, in state governments, and at all levels to convey a coherent and consistent message

Paul Hallacher, Pennsylvania State University.

that innovation is important and what might be done from a policy perspective to enhance the innovation ecosystem. A second perspective overlaps with the Talent Working Group, and that is how do we inspire young people and educate them through unique educational experiences to be innovative and entrepreneurial. The last perspective is public outreach—how we convey the value of innovation to people through the media."

Hallacher noted that the group focused a lot of its attention on the policy advocacy perspective because innovation policy can be controversial. For example, the DOE Energy Efficient-Building Hub headquartered at Penn State is an innovation policy approach that some members of Congress do not feel is worthwhile. Advocacy plays an important role in mitigating controversy by explaining to policymakers on both sides of the political spectrum the value of public-private partnerships in innovation and competitiveness.

Recognizing that every member of Congress has important research facilities and industrial organizations in their districts, the group recommends creating local councils made up of research universities, national laboratories, industry and small businesses to meet with members of Congress and local officials in their districts to advise them on an ongoing basis and educate them about the innovation assets in the region. "When the seat changes to another elected official," Hallacher stressed, "you continue to advise the seat, not the person. We, as the science and engineering community, should take it upon ourselves to form such councils and provide advice to our members and our districts, with an overarching theme that comes from the Council on Competitiveness and similar organizations." Using this model, Hallacher suggested a pilot project with strategic members of Congress.

Chris Mustain presented the update for the Regulation Policy Working Group. Mustain reminded participants that the TLSI Dialogue 6 Pre-Report discusses the policy and regulatory issues in greater detail, and therefore he would only highlight some of the major recommendations.

One issue the group feels would have a great impact is overhauling international trade in arms regulations (ITAR) that control U.S. exports. President Obama announced an ITAR reform agenda in 2010 to create a single export control list, a single primary enforcement agency, a single IT system for export controls and a single licensing agency. Comments were collected on proposed regulations that are still under review. Realizing the reform effort's objectives will take more than regulations. Congress needs to pass legislation for it, but the Chair of the House committee with lead jurisdiction has expressed skepticism of such sweeping reform. The working group would like to advance export reform by evaluating the administration's reform proposal and engaging the administration and Congress to pursue the reforms deemed essential.

Another issue of concern for the group is federal support for basic research. Mustain praised the increased financial support as a result of the Council's National Innovation Initiative and the corresponding legislation, the America COMPETES Act. However, budget constraints and the looming debt and deficit issues have reduced federal support, which Mustain explained was a critical issue. "If we continue to take those budgets down five to ten percent per year, it's not going to be very long before we will be back to funding levels of FY 2007 that we thought were inadequate to generate the innovation our country is going to need to be competitive."

The group also focused on the issue of high-skilled immigration reform. The primary challenge is decoupling this issue from the broader illegal immigration debate. Mustain affirmed that politicians on both sides of the aisle generally support giving green cards to Ph.D. graduates from outside the United States, but the upcoming election year will challenge progress on this issue.

In closing, Mustain discussed patent and tax reform issues. He reviewed the recently enacted America Invents Act that creates a first to file patent system, new regulations to reduce litigation, mechanisms to reduce the patent application backlog and fast-track procedures for patent applications.

Mustain noted that the one working group recommendation on which little progress has been made is to remove conflicts between the tax code and regulations governing university research. Mustain cited the example of using tax exempt bonds to build research facilities. Internal Revenue Service rules limit public-private collaboration in such facilities, but the funding from research agencies is often conditioned on establishing such partnerships. Promoting regulatory cooperation is an important objective of the group.

Cheryl Martin, Advanced Research Projects Agency – Energy, and Chris Mustain, Council on Competitiveness.

Discussion

Jim Phillips, chairman and CEO of NanoMech, complimented the report of the Accelerating Innovation Working Group as being comprehensive and actionable. Phillips called attention to the importance of the second objective to build communities of commercialization and entrepreneurship. "I believe that there is a tremendous amount of stranded intellectual property in our universities and labs, and these recommendations will help address that." He suggested that the group also consider calling for an incentive that the government would offer universities to commercialize their IP through small companies.

Wince-Smith suggested that the group consider possible test-bed technologies on which the U.S. public and private sectors could focus their efforts. She suggested materials as a possible example because of the importance of rare-earth minerals and need to develop substitutes or new extraction technologies. The test bed technologies, Wince-Smith said, should be "game-changers for our nation's future."

Bart Gordon, K&L Gates and Council on Competitiveness, and Jim Phillips, NanoMech.

Bart Gordon, partner at K&L Gates and a distinguished fellow with the Council, replied that ARPA-E is working on several such energy-related projects, including rare earth substitutes. He suggested that the TLSI might be most helpful by organizing communities of interest that could help span the production valley of death. "ARPA-E can get them through the proof of concept and prototype valley, but not the second one," he commented.

William Brinkman, director of the DOE Office of Science, commented that the DOE is heading in the direction outlined by Wince-Smith through the creation of regional "hubs" of directed research to accomplish specific goals. He noted the Fuel-from-Sunlight hub in California and future plans for a hub focused on battery technology. In each case, the Department channels funding from multiple sources to government-university-private sector partnerships centered in a region, thus building a community of expertise.

Johnson and Phillips praised the Talent Working Group's focus on community colleges. Johnson suggested that many U.S. students who earn college degrees may be better served by vocational or technical educations. He also suggested that the term "vocational education" might be re-branded, perhaps to "career readiness," to confer an equal value between career skill training and a college education. Phillips agreed, and added that most high schools have dropped shop classes and other instruction in skilled trades from their course work. He urged that that trend should be reversed so some level of training begins before entering a community college or trade school.

Frank Douglas, president and CEO of the Austen BioInnovation Institute in Akron, suggested that community colleges bring in faculty from industry to work in conjunction with existing faculty on courses around practical industry problems. Mustain noted that the AACC is developing a set of recommendations/reforms, and that the TLSI could partner with them to advance such ideas.

Gordon reminded participants of the shortage of teachers with math and science backgrounds. He cited data from the *Rising Above the Gathering Storm* report that 58 percent U.S. middle school math teachers have neither a certification nor background in math. He also noted that 92 percent of physical science teachers have neither a certification nor a degree in the physical sciences. "If you don't have a teacher with a core understanding, they can't inspire," he stated. Gordon suggested that the Council advocate scholarships for math and science students who agree to teach for five years after earning their degree. He also supported programs to bring industry professionals into schools and to shift responsibilities for some of these programs from the National Science Foundation to the Department of Education, which has more resources.

Andrew Garman, founding partner at New Venture Partners, observed that many recommendations require congressional action. How much time do we have to make the impact that we desire?" he asked rhetorically. Garman suggested that TLSI participants consider additional ideas on how agencies and non-

Andrew Garman, New Venture Partners.

Thomas Guevara, United States Department of Commerce, Economic Development Administration.

governmental actors can take action without waiting on Congress. He also urged new ideas on how to drive change on issues like immigration law. "I think we have the clout to have that discussion irrespective of what administration is in power. We should focus our energy in a way that lays a timetable for outcomes on the issues we choose."

Garman also emphasized that a serious discussion about investments in innovation should be undertaken within a larger framework of how those investments will be paid for as part of a long-term plan to tackle America's fiscal imbalances. "It is a substantive and serious exercise to ask for money on an escalating basis for our priorities," he postulated.

Thomas Guevara, deputy assistant commerce secretary with the Economic Development Administration (EDA), suggested creating a national dialogue about innovation infrastructure. The focal point, he stressed, should be employer outcomes. "We need employers to demonstrate how public-private investments in innovation infrastructure result in real job gains longitudinally, increased wages longitudinally, as well as setting the basis for additional innovation."

Evans reminded the group about the online survey distributed to TLSI members and encouraged them to participate. The survey could be an important tool for the Council to suggest technology priorities for the nation. Building on Hallacher's outreach remarks, Evans described the Forum for Innovation and Technology, an outreach model the Council used in the past to educate members of Congress and their staff about important legislation linked to innovation. The forum created a cadre of innovation experts on Capitol Hill, Evans noted. "That had a huge benefit when legislation like America COMPETES was presented, because folks there had eight or nine years of indoctrination as to why innovation is important." Evans urged the outreach group to consider a similar model in addition to its proposal to reach out through standing regional forums.

PART 2: FINDINGS FROM TLSI DIALOGUE 6

Federal Outlook for Science, Technology and Innovation

Dr. Cyrus Wadia
Assistant Director, Clean Energy and Materials R&D
White House Office of Science & Technology Policy

I am going to discuss the Material Genome Initiative, a White House effort on advanced materials with a call to action including specific deliverables that this group could potentially adopt. Before I describe the Material Genome Initiative, however, let me give an overview of how the White House is thinking about innovation.

The President's Strategy for American Innovation has three key themes. The first is investing in the building blocks of American innovation. The second is promoting market based innovation, and the third is catalyzing breakthroughs for national priorities. The Office of Science & Technology Policy (OSTP) and the rest of the White House are doing a lot of heavy lifting on the themes that we have been talking about today—STEM education, shaping priorities in research and development that would go into the president's budget, as well as making sure these priorities filter through some of the other proposals like the American Jobs Act, the StartUp Act and the America Invents Act.

But we are also involved in some smaller things that potentially could have a more dramatic impact and lead to innovation in a broader ecosystem. These efforts speak more to the idea of public-private relationships or soft infrastructure. For example, there is an effort with veterans called Blue Button, which is a single point where veterans can download all their health information and share it with whatever health provider or other third party they would like. This had such a dramatic impact that the Robert Wood Johnson Foundation launched Blue Button.org

Chad Evans, Council on Competitiveness; Cyrus Wadia, White House Office of Science and Technology Policy; and Deborah L. Wince-Smith, Council on Competitiveness.

this past September to allow all consumers in the United States to have a similar type of service. I'd also like to tell you about a project spearheaded by the nation's chief technology officer, Aneesh Chopra, which has nothing to do with federal action but relies on state and other external stakeholder action. It's called Green Button, which is the equivalent to Blue Button in the consumer energy space. Working with the three major utilities in California, the initiative will open up consumer data to individual users of energy in a simple format and could be shared with third party vendors. The reason this is significant is that utilities have often been an obstacle in opening up this information, which would enable more innovation. The data transparency should enable California to take a lead role in smart grid technology innovation.

The Materials Genome Initiative falls under the third bullet in the president's innovation strategy, catalyzing breakthroughs. The initiative is a broad effort to reduce the time and cost it takes to get material from conception to market. Currently, it takes 20 to 30 years on average, and that's just far too long. We want to bring that down to around five years, and we believe we can do it in three key ways. The first is developing the materials innovation infrastructure. The second is achieving national goals in energy security and warfare with advanced materials. The third is equipping our next generation workforce.

As an interagency coordinator, OSTP has been working with the Department of Energy, the National Science Foundation, the Department of Defense, and the National Institute of Science and Technology to construct this vision. The president announced the initiative in June with a call for $100 million in the president's budget across those four agencies, of which about 50 to 60 percent is going to be newly allocated funds.

There are four cross-cutting themes. The first is incentivizing open paradigms—sharing and access to tools. This relates to the innovation infrastructure that I was describing, which has computation, experimentation and data all on an equal footing. We believe the lynchpin of this initiative could be the data that enables us to communicate information between scientists in national labs and industry; between individual theoretical scientists who are trying to develop new computational tools for predicting material behavior and industrial engineers who are trying to deploy this in the field. The problem we've seen with the materials continuum—the reason why we've had this 20 to 30 year time frame—is that the materials community by definition tends to be very fragmented, and there's very little incentive right now to offer open access to information such as data properties or engineering requirements. We want to break through that and create the right type of environment.

The second cross cutting theme is developing innovation ecosystems. We don't want to build infrastructure in a vacuum. We want clusters of activity that are focused on specific materials problems, be it alloys for light weighting vehicles or new protective material for soldiers in the field. We want to facilitate innovation ecosystems which would include industry, the public sector, universities, research labs and other stakeholders. It would be easy to see incorporating the large original equipment manufacturers, universities and national labs, but in many cases the small and medium-sized businesses that are part of the supply chain have very little resources to access these types of tools; to train their workers; to be part of this solution. We need to figure out ways to encourage that.

The third cross cutting theme is the infrastructure itself and driving innovation across the computation, experimentation and data informatics. One example of this is in the predictive properties of materials. Looking at an early stage research discovery project on battery electrodes, the tools we use to model electronic behavior of those materials is a very poor predictor. We often talk about "materials by design," and this is part of it. We also talk a lot about multi-scale models as part of the solution. We want the right type of effort to make those models better, and we believe that there is a link between experimentalists, computational scientists, industry and academia to bring that to fruition.

The last theme is catalyzing a shift in culture across the entire set of stakeholders and scaling these investments and efforts. We often don't talk about this as an initiative per se, but as a movement in the materials community—and the government is playing a small catalytic role.

That is our vision. In addition to the funding priorities, we are eager to get the seed capital into the system, and we're engaging with stakeholders to spur more external involvement. Some of the folks in this room have already had discussions with us on this point, and I am very interested to see how we can better engage the TLSI and other efforts led by the Council on Competitiveness, because I believe there is a natural connection with our activities.

Discussion

Gordon kicked off the discussion with a few remarks. He introduced Cheryl Martin, the new deputy director of ARPA-E for Commercialization, and he praised the Department of Defense's (DoD) partnership with the DOE. "There is a very real commitment in their efforts to jump start alternative energy," he said. The DoD engaged for practical reasons of cost, resiliency and operational security, Gordon emphasized. He reminded TLSI participants that fuel in Afghanistan can cost $400 per gallon, and that many soldiers have been lost protecting fuel convoys.

Gordon, the former House Science and Technology Chairman, also pressed industry leaders to devote more effort and resources to support research appropriations. "There are a lot of folks in Congress right now who don't just want to cut research—they want to do away with research. There is a misguided, but sincere feeling among many that if something is worth doing, if there's a benefit from research, then the private sector will do it—not really understanding the difference between applied and basic research." Gordon noted that although many top industry leaders and business associations cite federal research as one of their top five priorities, most of their lobbying resources are devoted to tax and regulatory issues.

Gordon also addressed immigration, echoing the TLSI sentiment that the U.S. system is overly restrictive and explaining that "high skill immigration has been held hostage to illegal immigration, and so nothing is getting done in Congress." He praised Representative Lamar Smith's Legal Workforce Act, however, as a step in the right direction. The bill would not raise the number of immigrants allowed into the United States, but would lift restrictions on the country of origin for those immigrants.

Jay Cohen, principal at the Chertoff Group, supported Gordan's point about basic research. "Only the federal government has the deep pockets and the patience to make the investment in the basic research through the national labs and universities," he said. Cohen continued, "Without sustained investment in basic research by the federal government, all the other benefits we are talking about will accrue to countries that follow the model we've used so successfully for six decades." Brinkman agreed, noting that several countries are proving more willing to invest in longer term projects than the United States.

Phillips also agreed with the importance of research investment, but reiterated his concern that "as a country, we don't harvest that incredible technology out of the labs and universities nearly as well as we could." Phillips stressed the importance of improved technology transfer and commercialization policies.

Johnson closed by stating that adequate money and ideas are available for commercialization in the United States, but that uncertainty is creating risk aversion. "People are looking for stability in policy, the market place and the economy before they make capital investments in these innovations," he said.

PART 2: FINDINGS FROM TLSI DIALOGUE 6

High Performance Computing Initiative

Johnson introduced Brinkman and Tomás Díaz de la Rubia, deputy director for science and technology at Lawrence Livermore National Laboratory, to lead a discussion on High Performance Computing. Díaz de la Rubia began with giving an update on the Council's High Performance Computing (HPC) Initiative, which he co-chairs with Michael McQuade, senior vice president for science and technology at United Technologies, and Bob Buhrman, senior vice provost for research at Cornell University.

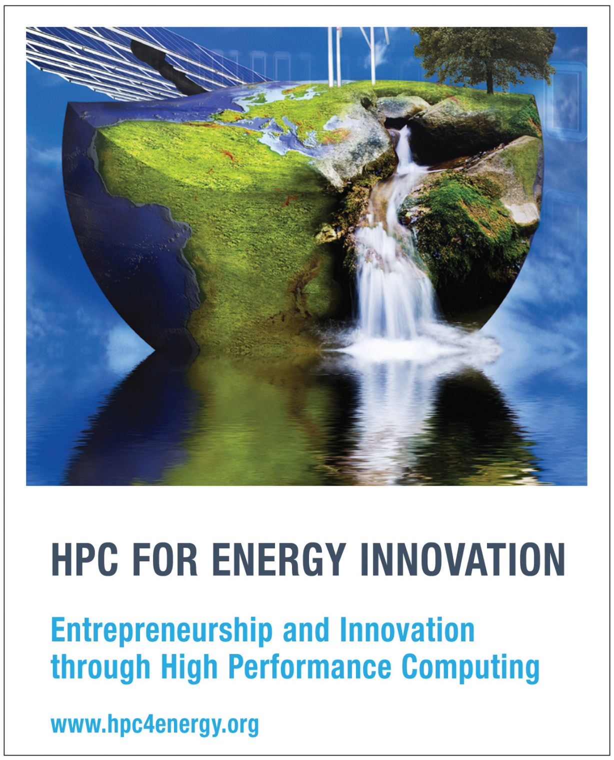
Díaz de la Rubia explained the Council has promoted the use of high performance computing as an accelerator for innovation for many years. The purpose of the HPC Initiative is to facilitate access to computing capabilities at national labs and universities to help accelerate innovation in the private sector and enhance the nation's competitiveness.

Díaz de la Rubia shared observations from a recent visit to China that he and Wince-Smith took to better understand HPC developments there. He described the delegation as surprised by the level of investment and speed with which progress has been made. Though Chinese computing centers are now using U.S. components, "they surprised us by how aggressively they're developing indigenous technologies—their own semiconductor chips, memory, interconnections, and own logic." Díaz de la Rubia noted Chinese intent to lead global markets in these technologies. He attributed much of their success to an influx of Chinese citizens who gained HPC experience in the United States.

The most important discovery the delegation found was how tightly the Chinese are linking supercomputing to industry. "They are coupling supercomputing with their industrial development in a very tight way," Díaz de la Rubia stated. "All their supercomputing centers are based on the idea of using high performance computing to accelerate indigenous technology development in energy, manufacturing, materials and aerospace—all industries around the Chinese five year plan."

Tomás Díaz de la Rubia, Lawrence Livermore National Laboratory, and William Brinkman, U.S. Department of Energy Office of Science.

To advance HPC usage for U.S. competitiveness, Díaz de la Rubia announced a new pilot program at Lawrence Livermore National Laboratory called "hpc4energy incubator." The idea behind the program, he explained, "is to launch an incubator in which U.S. companies gain access not only to computers, but also access to ecosystems—teams of people, computer scientists, mathematicians, algorithm experts, domain scientists in different energy technology sectors, and basic researchers inside the laboratory." Industry will be able to leverage these teams to advance a particular program in energy technology.



Brinkman offered several examples of HPC capabilities in the national lab system being used to advance U.S. competitiveness. He noted modeling for multi-component materials "that you couldn't imagine in the very recent past." He shared efforts that reduced wind drag on trucks and planes, and shared that the DOE has the computing capability to run large systems, as it does for other government agencies, that might be extended to the private sector. "There are ways in which we can really change the dimension of how computers are used," Brinkman stressed.

The DOE science director also asserted that "we have every intention of trying to stay in the competition for the best capability in the world. We think we will have very shortly a three exascale machine on line." By the end of 2012, Brinkman predicted that 10 to 20 exascale machines could be online. "The next 10 years are going to be very interesting times in computing, and the Department intends to keep the country at the forefront of developing and using very high-speed computing."

Discussion

Tilak Agerwala, vice president of systems at IBM, began the discussion by calling the group's attention to the challenge of developing software for HPC. "I am really worried about the ability of the Chinese to put together a complete software ecosystem and the applications. That's where I think we need a lot more focus if we're going to get HPC into the hands of small to medium businesses and large enterprises." Agerwala concluded by suggesting the Council focus on the development of a software ecosystem for HPC along with the development of hardware.

Díaz de la Rubia agreed with Agerwala and stated that the Chinese have a funding advantage over the United States in the development of a software ecosystem. "The Chinese have a relative advantage because they have an open book and the talent, whereas we have a lot of sunk investments over decades and a particular way of writing software for these machines. We don't have a lot of investment in writing software for big data."

Ravi Iyer, vice chancellor for research at the University of Illinois, commented on how the United States does not have as high of a level of investment in HPC as China, and probably will not for the foreseeable future. Iyer asserted that America must focus its investments in basic research and develop a framework where labs and universities collaborate with industry to develop innovation.

PART 2: FINDINGS FROM TLSI DIALOGUE 6

The Path Forward: Implementing the TLSI Agenda

Evans reiterated the idea put forth for the TLSI to develop a series of high-impact project opportunities framed around the recommendations created by the group.

The co-chairs thanked participants and emphasized the importance for TLSI moving forward to develop and implement projects to gain value from the recommendations.

Wince-Smith thanked participants and the Naval Academy for hosting the meeting. She echoed the importance of the TLSI initiative moving forward to take action on the recommendations. She also suggested framing several objectives of the TLSI as national security issues.

Conclusion

Throughout the TSLI Dialogues, participants have emphasized that issuing recommendations will not be enough. They expect to engage public and private sector stakeholders to ensure that the U.S. environment for research and technology commercialization is improved tangibly. To that end, the Council looks forward to establishing an implementation road map, committing to an aggressive agenda and measuring results.

As evidenced by the Council's pioneering *Innovate America* report of the National Innovation Initiative, good ideas and hard work can translate words into deeds. TLSI members are aware of the political obstacles to enacting meaningful reforms, but they are equally aware of the opportunities that could be unleashed by those reforms—opportunities that could usher in new innovations that could transform America's economy and make life dramatically better for millions of people.

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The Council on Competitiveness is the only group of corporate CEOs, university presidents and labor leaders committed to ensuring the future prosperity of all Americans and enhanced U.S. competitiveness in the global economy through the creation of high-value economic activity in the United States.

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- Forging public and private partnerships to drive consensus
- Galvanizing stakeholders to translate policy into action and change

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