Technology Leadership and Strategy Initiative

Integrate.

Dialogue 8:
New Collaboration Dynamics at Home and Abroad

Compete.
Council on Competitiveness

Dialogue 8: New Collaboration Dynamics at Home and Abroad

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October 22, 2012
Virginia Tech Research Center, Arlington, VA

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Table of Contents

TLSI DIALOGUE 8

Letter from the President

On behalf of the Council on Competitiveness (Council), it is my pleasure to release *Integrate,* the report on Technology Leadership and Strategy Initiative (TLSI) Dialogue 8. The TLSI brings together American technology leaders from companies, universities and laboratories to set the national agenda for research, technology and commercialization.

I extend special thanks to the co-chairs who make the TLSI possible—Dr. Klaus Hoehn, Vice President, Advanced Technology and Engineering for Deere & Company; Dr. Ray O. Johnson, Senior Vice President and Chief Technology Officer of the Lockheed Martin Corporation; and Dr. Mark Little, Senior Vice President and Chief Technology Officer of the General Electric Company and Director of GE Global Research.

This report has two components. Section one, the "pre-report," sets the stage for TLSI Dialogue 8 by explaining how regional innovation economies are tethered increasingly to national and global networks of expertise. The global competition for talent and research and development (R&D) investment illustrates this trend, as does the influence of policymaking outside the region's control. Section one also examines how the proximity of R&D and manufacturing activities can influence the competitiveness of each.

Section two, the "post-report" presents the proceedings of TLSI Dialogue 8 held on October 22, 2012, at the Virginia Tech Research Center in Arlington, VA. The Council thanks our host Dr. Donald Leo, Vice President and Executive Director of National Capital Region Operations at Virginia Polytechnic Institute and State University (Virginia Tech). I also am grateful to our speakers: the Honorable David T. Danielson, Assistant Secretary for Energy Efficiency and Renewable Energy, U.S. Department of Energy; Dr. Reginald Brothers, Deputy Assistant Secretary

for Research, U.S. Department of Defense; Dr. Erik Straser, General Partner at Mohr Davidow Ventures; Dr. Montgomery Alger, Vice President and Chief Technology Officer of Air Products and Chemicals; Dr. Ajay Malshe, Founder, Executive Vice President, and Chief Technology Officer of NanoMech, Inc.; and Dr. Paul Hallacher, Director of Research Development Programs at The Pennsylvania State University (Penn State).

Sincerely,

Deborah L. Wince-Smith

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

The TLSI dialogues are 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 federal government.

TLSI DIALOGUE 8

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TLSI DIALOGUE 8

Agenda

MORNING

8:00 Registration and Continental Breakfast

8:30 Opening Remarks

The Honorable Deborah L. Wince-Smith
President and Chief Executive Officer
Council on Competitiveness

Dr. Ray O. Johnson
Senior Vice President and Chief Technology Officer
Lockheed Martin Corporation

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

9:00 Overview of the Virginia Tech Research Center

Dr. Donald Leo
Vice President and Executive Director, National Capital Region Operations
Virginia Polytechnic Institute and State University

9:15 New Collaboration and Partnership Models—Seizing the Clean Energy Manufacturing Opportunity

The Honorable David T. Danielson
Assistant Secretary
Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy

10:30 Coffee Break

11:00 New Ways to Access Innovation & Talent

Dr. Erik Straser
General Partner
Mohr Davidow Ventures

Dr. Montgomery Alger
Vice President and
Chief Technology Officer
Air Products and Chemicals, Inc.

AFTERNOON

12:30 Lunch

1:15 Integrating Modern Production Considerations into the Innovation Process – How Significant Is the Link between Research and Manufacturing?

Dr. Ajay Malshe
Founder, Executive Vice President, and Chief Technology Officer
NanoMech, Inc.

Dr. Paul Hallacher
Director, Research Program Development
The Pennsylvania State University

2:00 Initiative Update: High Performance Computing

Dr. J. Michael McQuade
Senior Vice President, Science and Technology
United Technologies Corporation

Ms. Dona Crawford
Associate Director for Computation
Lawrence Livermore National Laboratory

2:30 Defense Department Research and Development Priorities

Dr. Reginald Brothers
Deputy Assistant Secretary for Research
United States Department of Defense

3:00 TLSI Update

Mr. Chad Evans
Senior Vice President
Council on Competitiveness

3:15 Closing Remarks

The Honorable Deborah L. Wince-Smith
President and Chief Executive Officer
Council on Competitiveness

3:30 Conclude

Part 1:
Pre-Report for
TLSI Dialogue 8

PART 1: PRE-REPORT FOR TLSI DIALOGUE 8

Introduction

A young man of 25 traveled in August of 1881 from the Germantown area of Philadelphia to the summer resort town of Newport, Rhode Island. Over four days spilling into early September, he and a colleague from his local tennis club, Clarence Clark, competed on the green lawns of the famous Casino (Figure 1) that now serves as the International Tennis Hall of Fame. A string quartet played classical music throughout the matches as he and Clark progressed through the field. The pair defeated their final opponents in straight sets, 6-5, 6-4, 6-5 to claim the first doubles crown of the United States National Lawn-Tennis Tournament—now known as the U.S. Open Tennis Championships.

The young victor, Frederick Winslow Taylor, was destined to be known for much more than a sports footnote. In his time, he would be mentioned alongside Thomas Edison and Henry Ford as an innovator. He earned both national acclaim and scorn, punctuated by a series of Congressional hearings in 1912 that examined the reforms he ushered into the American workplace—and eventually those of the world.

Born to a prosperous Philadelphia family in 1856, Taylor would revolutionize how organizations are managed. A pioneer in business process innovation, he is considered one of first business consultants and deployed scientific methods to improve human and mechanical efficiency. A century later, it is worth examining why Taylor was so controversial and why he remains relevant today.

Taylor's life was marked by diverse experiences and accomplishments. As an early teen, his family lived and toured through Europe for several years, supported by his father's earnings in the mortgage industry. After completing some of his studies in Europe, Taylor returned to the United States in 1872 and enrolled in Phillips Exeter Academy. Although he passed the Harvard entrance exam with honors in 1874, Taylor elected instead (possibly due to vision issues) to become an apprentice patternmaker and machinist at a pump manufacturing company in Philadelphia. After completing the apprenticeship, he was hired by the Midvale Steel Works and rose rapidly from the shop floor to foreman and chief engineer of the works.

While at Midvale Steel Works, Taylor enjoyed a rather remarkable decade. In addition to his tennis exploits, Taylor earned several of the 42 patents he would earn during his life—mainly for industrial machines and a few for sporting equipment, including a novel tennis racket (Figure 3). In 1883, he completed his night studies and earned a degree in mechanical engineering from the Stevens Institute of Technology.

Most important in the 1880s, however, was the beginning of his life's work that would make him famous. He observed at Midvale Steel Works that employees did not do as much work as they might reasonably be expected to perform and that management, machinery and incentive systems tended to be driven by "rule of thumb" rather than by carefully researched practices. Taylor began studying the time it took workers to perform various tasks in different ways and scrutinized how the plant was organized and managed. He suggested that one optimal way to maximize production efficiency could be found through scientific means. In 1884, Taylor became the chief engineer at Midvale Steel Works, designing and constructing a machine shop based on these principles.[1]

1 Mee, John F. Encyclopedia Britannica. www.britannica.com/EBchecked/topic/584820/Frederick-W-Taylor.

Figure 1. Newport Casino, Rhode Island

From this beginning emerged Taylor's doctrine of scientific management. In the 1890s, Taylor took his principles to several firms like Bethlehem Steel. Although he continued to invent devices and co-developed the Taylor-White process for hardening steel, his great contribution would be his new profession as a consulting engineer for management.

"Frederick W. Taylor was the first man in recorded history who deemed work deserving of systematic observation and study," Peter Drucker wrote.

"On Taylor's scientific management rests, above all, the tremendous surge of affluence…which has lifted the working masses in the developed countries well above any level recorded before." Drucker further described Taylor as "the Isaac Newton (or perhaps the Archimedes) of the science of work."[2]

2 Drucker, Peter F. Management—Tasks, Responsibilities, Practices. Harper & Row, 1973.

Figure 2. Frederick Winslow Taylor

Taylor unveiled much of his thinking through publications in the Transactions of the American Society of Mechanical Engineers, such as “Notes on Belting” (1894); “A Piece-rate System” (1895); “Shop Management” (1903); and “On the Art of Cutting Metals” (1906). Taylor advocated a top-down management strategy that moved American plants from craft shops to mass production facilities. Work was to be broken into smaller, routine tasks that could be learned more easily and performed more efficiently. Management was charged with finding and implementing the most productive and efficient means to utilize men and machines, enabling the adoption of best practices.

Taylor’s methods resulted in large productivity gains for his clients, and word of his techniques spread. In some shops, however, workers resented managers with stopwatches, having little to no input on new procedures, and potential job loss as fewer people could achieve the same output.

In 1910, future Supreme Court Justice Louis Brandeis leveraged Taylor’s ideas in a case he had before the Interstate Commerce Commission on railroad rates. Brandeis coined the term “scientific management” to describe techniques that could ease the strain on workers even as it raised their pay and increased profits for owners. Brandeis argued that scientific management would enable wage increases without increases in railroad rates. The Eastern Rate Case, as it came to be known, generated national interest in Taylor and efficiency management. “I have rarely seen a new movement started with such great momentum as you have given this one,” Taylor wrote to Brandeis.[3]

In 1911, Taylor published *The Principles of Scientific Management*, laying out his principles for mass production.

Author Robert Kanigel describes competing views of scientific management at the time. “Taylor was the first efficiency expert, the original time-and-motion man. To organized labor, he was a soulless slave driver, out to destroy the workingman’s health

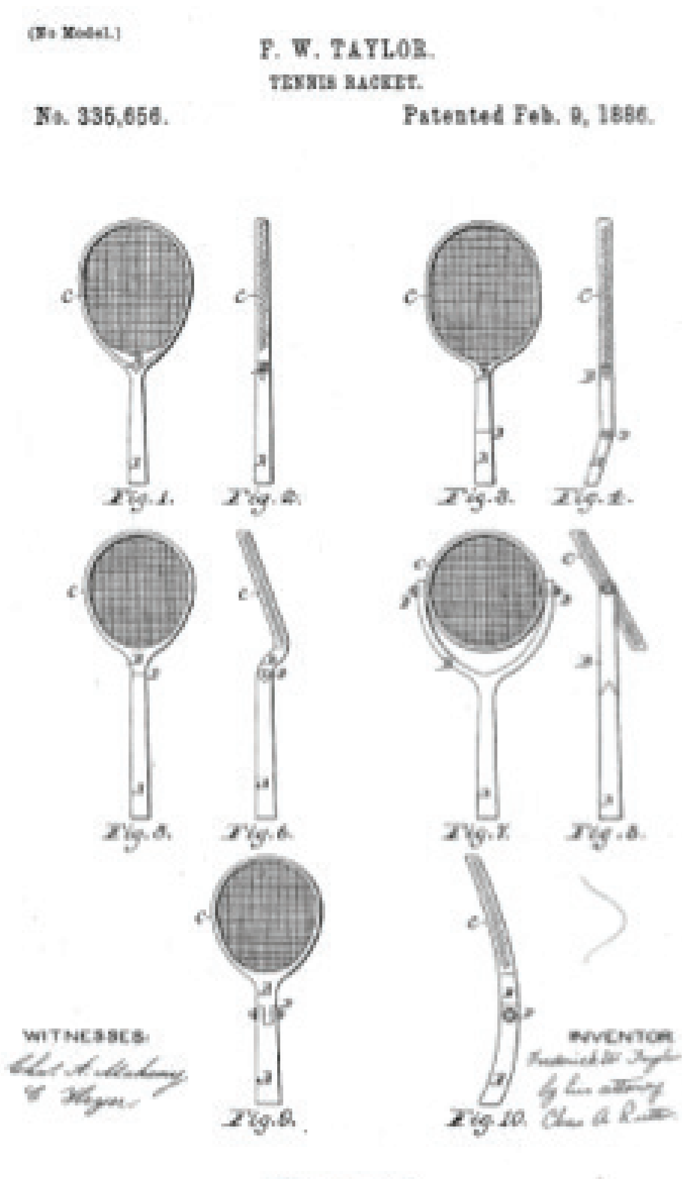
3 Gale Encyclopedia of Biography. Frederick Winslow Taylor. www.answers.com/topic/frederick-winslow-taylor.

and rob him of his manhood. To the bosses, he was an eccentric and a radical, raising the wages of common laborers by a third and paying college boys to click stopwatches. To him and his friends, he was a misunderstood visionary, possessor of the one best methods that, under the banner of science, would confer prosperity on worker and boss alike, abolishing the ancient class hatreds."[4]

Taylor recognized the risk of backlash, writing "the knowledge obtained from accurate time study…is a powerful implement, and can be used, in one case to promote harmony between workmen and the management, by gradually educating, training, and leading the workmen into new and better methods of doing the work; or in the other case, it may be used more or less as a club to drive the workmen into doing a larger day's work for approximately the same pay that they received in the past."[5]

In Taylor's mind, "the principal object of management should be to secure the maximum prosperity for the employer, coupled with the maximum prosperity for each employee. The words 'maximum prosperity' are used, in their broad sense, to mean not only large dividends for the company or owner, but the development of every branch of the business to its highest state of excellence…In the same way maximum prosperity for each employee means not only higher wages…but…also means the development of each man to his state of maximum efficiency, so that he may be able to do, generally speaking, the highest grade of work for which his natural abilities fit him."[6]

Figure 3. Taylor Tennis Racket



4 Kanigel, Robert. The One Best Way. Frederick Winslow Taylor and the Enigma of Efficiency. MIT Press, 1997.

5 Taylor, Frederick W. The Principles of Scientific Management. 1911.

6 Ibid.

From September 1911 to January 1912, the House Committee to Investigate the Taylor and Other Systems of Shop Management "met in four cities, heard from iron molders and machinists, steamfitters, army officers, union officials, other efficiency experts—60 witnesses in all; testimony taken [that] would fill almost 1,400 pages of printed text."[7] This effort culminated in a January 1912 hearing where House members heard testimony and sparred over several days with Taylor himself.

Over time, management science modified or turned away from several Taylor precepts. His influence, however, remains strong. Productivity gain from workers, technology, and systems is still pursued aggressively and subject to rigorous scientific research. It is widely held that competitiveness—for firms, localities and nations—is an outcome of productivity.

Participants in the TLSI recognize a two-way link between innovation in technology and processes. On one hand, technologies such as computing or 3D printing force a reconsideration of current processes in order to leverage the technology. On the other hand, the process and rules by which companies, universities and national laboratories develop new technology for commercialization can determine whether a technology gains traction in the market and creates wealth and jobs. TLSI dialogues have frequently referenced reports, consultants, ideas and metric development efforts aimed at improving the management of innovation—and innovation productivity by extension.

TLSI Dialogue 8 will examine several emerging issues in innovation management, such as how regional innovation clusters can tap into global networks of expertise. Participants will consider which innovation models or practices overseas should be considered in the United States, which industries require tightly integrated research and production functions, and how production considerations might be integrated into contemporary innovation strategies. The TLSI also will continue to examine best practices in commercialization by universities, laboratories and companies.

7 Kanigel, Robert. The One Best Way. Frederick Winslow Taylor and the Enigma of Efficiency. MIT Press, 1997.

PART 1: PRE-REPORT FOR TLSI DIALOGUE 8

Tapping into Regional and International Innovation Networks

Legacy of Council Work

For more than a decade, the Council has been at the forefront of thought leaders on regional innovation (Figure 4). Under the leadership of Dr. Michael E. Porter, Bishop William Lawrence University Professor at the Harvard Business School, and Mr. F. Duane Ackerman, then Bell South CEO and former Vice Chairman of the Council, the Council published in 2001 *Clusters of Innovation: Regional Foundations of U.S. Competitiveness*. This groundbreaking report and corresponding initiative developed a framework to evaluate cluster development and innovation performance at the regional level. By offering cluster theory as an organizing principle and innovation as an outcome, the Council set off an explosion of activity in theoretical and applied research and in practical steps to foster innovation across America and throughout the world.

In 2005, the Council teamed with the U.S. Department of Commerce to build capacity in qualifying regions. The resulting report was released in two parts—*Regional Innovation, National Prosperity* and *Measuring Innovation: A Guidebook for Conducting Regional Innovation Assessments*. The reports offer tools for building innovation-led regional economies and lessons from demonstration projects across the nation. The Council also has issued regional case studies and additional reports that explain how regions can engage business leaders and map their assets.

The Council's most recent regional innovation report *Collaborate: Leading Regional Innovation Clusters* addresses questions about the kind of leadership required for regions to harness their assets to accelerate economic growth and create jobs. Meaningful regional action requires a distinctive kind of leadership because political jurisdictions in the United States typically do not correspond to economic regions, thus impacting the ability to make sound decisions on a regional basis.

Greater Global Integration of Innovation

Participants in the TLSI dialogues have noted in many ways that innovation capacity is diffusing across the world as regions and nations strive to compete on the bases set forth in Council publications, including those previously mentioned. On metrics like talent, research investment, infrastructure and patents, America's competitors are closing the gap.

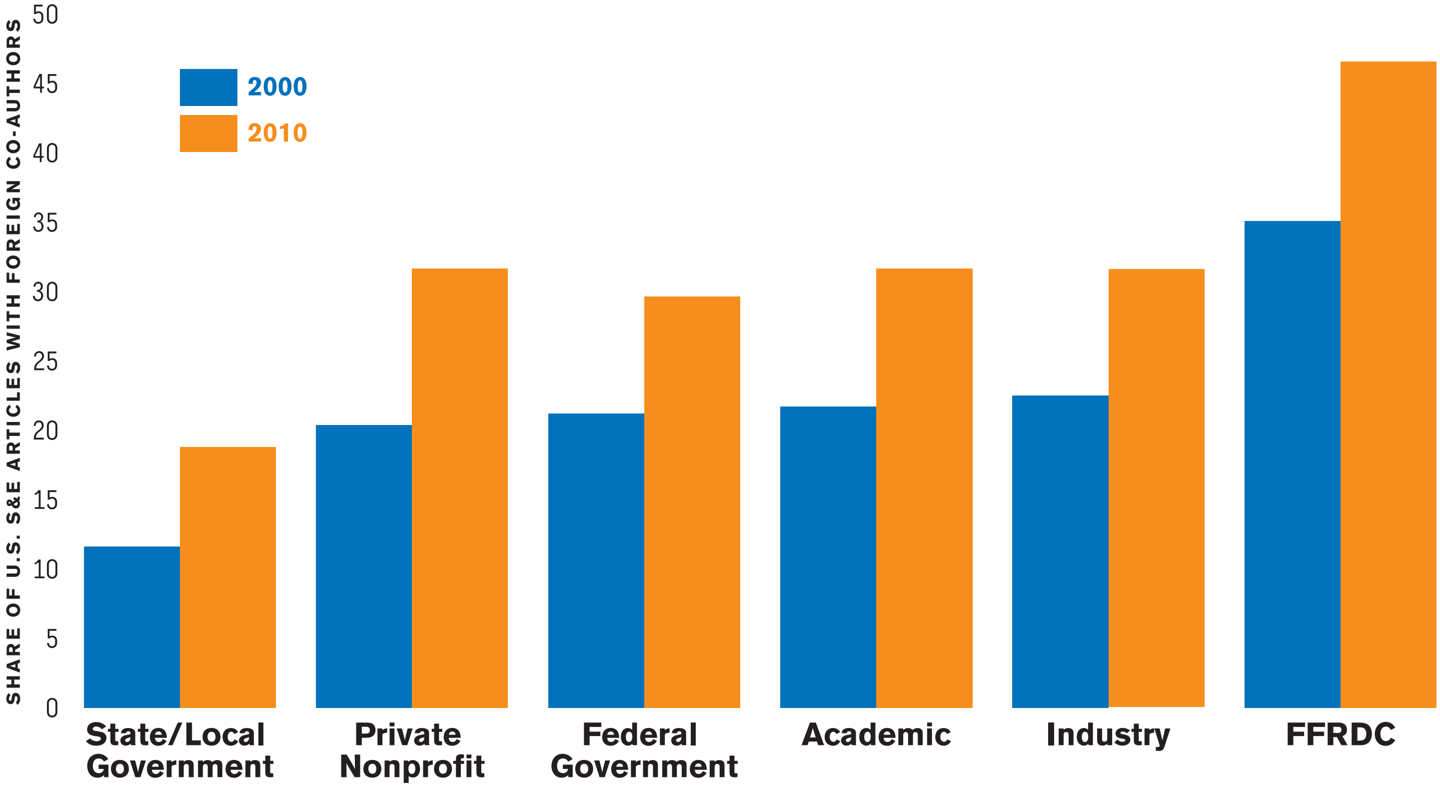
Less insight, perhaps, has been shared about how these emerging regions of innovation across the globe are becoming not isolated islands, but more often terrains tethered to international networks of expertise. A working paper from the Organization for Economic Cooperation and Development (OECD) notes: a "key issue for regions is that many of the determinants of their regional capacity are external to the region: funding decisions made by science councils, investment decisions made by large firms, and purchasing decisions made by original equipment manufacturers all shape the environment within which regions innovate."[8] The OECD paper suggests that policymakers consider how to improve the interfaces between actors in their regions and sectorial innovation systems that can span the globe.

8 Benneworth, P. and Dassen, A. Strengthening Global-Local Connectivity in Regional Innovation Strategies: Implications for Regional Innovation Policy. OEDC Regional Development Working Papers, January 2011.

Figure 4. Over a Decade of Council Leadership on Regional Innovation

Source: Council on Competitiveness.

Figure 5. Increase in International Engagement on S&E Articles by U.S. Actors
Source: National Science Foundation



Innovation actors are already increasingly connected to international expertise without a great deal of policy push. Between 2000 and 2010, for example, the share of U.S. academic articles in science and engineering with a foreign co-author rose from 21.7 percent to 31.6 percent.[9] In fact, the share of such articles with a foreign co-author rose significantly for researchers employed by the federal government, industry, federally funded research and development centers (FFRDCs), private non-profit organizations, and state and local government (Figure 5).

The global integration of America's innovation economy also applies to the flow of corporate research and development investment. Companies conduct and fund the majority of research and development (R&D) in the United States, and successful regions are attracting those resources, particularly from Europe. From 1998 to 2008 (the latest available data), R&D investment in America by the U.S. affiliates of European companies rose more than 84 percent, jumping from $16.4 billion to $30.3 billion (Figure 6). R&D investment by U.S. affiliates of Asian companies also rose 84 percent over that period, but from a much smaller base ($3.0 billion to $5.4 billion).

The United States remains an attractive location for foreign investment; foreign companies invest more R&D dollars in the United States ($40.5 billion) through their U.S. affiliates than U.S. firms invest abroad ($37.5 billion) through their foreign affiliates. The 10-year growth rates, however, have narrowed that gap (81 percent growth of foreign R&D flows into the United States compared to 152 percent growth into other countries by American firms).

Another oft-discussed metric of global integration is American reliance on foreign graduates to fill the ranks of its science and engineering (S&E) workforce. Almost 42 percent of America's S&E

9 National Science Board. Science & Engineering Indicators 2012. Chapter 5. National Science Foundation, 2012.

Figure 6. U.S. Inward and Outward Investment Flow of R&D
Sources: Bureau of Economic Analysis, Survey of Foreign Direct investment in the United States (Annual series); Survey of U.S. Direct Investment Abroad (annual series); *Science and Engineering Indicators 2012*.

R&D performed in the United States by U.S. affiliates of foreign companies, by investing region, and R&D performed abroad by foreign affiliates of U.S. multinational corporations, by host region. (Billions of current U.S. dollars)

		1998 ($22.4 B)	2008 ($40.5 B)
To United States from	Europe	16.43	30.28
	Canada	2.35	1.44
	Asia	2.96	5.44
	Latin America	0.40	1.80
	Africa	0.11	1.21
	Middle East	0.13	0.36
		1998 ($14.7 B)	2008 ($37.0 B)
From United States to	Europe	10.39	24.16
	Canada	1.75	3.04
	Asia	1.60	7.21
	Latin America	0.75	1.47
	Africa	0.04	0.06
	Middle East	0.14	1.06

NOTE: Preliminary estimates for 2008.

Figure 7. Foreign-born Workers in S&E Occupations, by Education Level (Percent)

Sources: National Science Foundation, National Center for Science and Engineering Statistics, SESTAT (2003-08), http://sestat.nsf.gov; Census Bureau, 2000 Decennial Census Public Use Microdata Sample (PUMS) and ACS (2003, 2006, 2008, 2009).

	2000	2003		2006		2008		2009
Education	Decennial Census	SESTAT	ACS	SESTAT	ACS	SESTAT	ACS	ACS
All College Educated*	22.4	22.6	24.2	24.0	25.3	24.8	24.9	25.2
Bachelor's	16.5	16.4	17.7	17.5	18.1	17.2	18.4	18.3
Master's	29.0	30.3	32.0	32.8	33.5	33.9	32.7	33.4
Doctorate	37.6	40.5	37.8	40.9	41.8	41.4	40.9	41.6

ACS=American Community Survey; SESTAT=Scientists and Engineers Statistical Data System

*Includes professional degrees not broken out separately.

NOTES: Includes all S&E occupations except postsecondary teachers because these occupations were not separately reported in 200 Census or ACS data files. SESTAT 2006 and 2008 data do not include foreign workers who arrived in the United States after 2000 Decennial Census and also did not earn S&E degree in the United States.

workforce with doctoral degrees is foreign-born, and across all levels of higher education the share has increased during the past decade (Figure 7). Regions seeking to retain this talent and source of vitality will have to do more than hope that federal immigration law improves; they will have to compete to attract these individuals against other U.S. regions, the individual's home country that may offer new opportunities, and competing innovation clusters all over the world.

Many have worked at developing regional innovation economies with varying degrees of success. Remaining competitive or competing more effectively, however, is not a simple or static exercise. Changes in technology, shifts in the economy, emerging practices, and an evolving global landscape require a culture of continual innovation—even in the manner that innovation is fostered.

Regional leaders face a number of challenges in their efforts to offer a policy environment and facilitate a culture that draws various actors together to generate wealth and jobs for the region. As noted by the OECD report cited previously, they face externalities. They also may need to re-engage their corporate, university, community college and investment communities to understand what kinds of global collaborations are underway and what might be done to build additional strategic ties and leverage more from existing ones.

As a group, innovation stakeholders in many regions would likely benefit from a fuller understanding of sectoral innovation networks and the dynamics of global supply chains for leading industries in their region. They might gain from establishing research partnerships, student exchanges, and regular dialogues with leading figures from innovation clusters outside the United States with complementary knowledge and resources. These types of actions could support expanded growth around a region's existing corporate base and efforts to launch new entrepreneurial firms.

Greater international engagement also might spotlight new approaches or institutions that generate proven and more productive innovation for the research dollars invested. For example, in past TLSI dialogues, participants suggested considering the Fraunhofer Institute model in Germany and the ways many foreign universities partner with companies.

Global Collaboration for Grand Challenges

During several TLSI dialogues, participants have identified grand challenges in which research and technology will play a major role in finding a solution or seizing an opportunity. Several of these challenges—in clean technology manufacturing; energy, food and water supplies; healthcare; space exploration; and security—extend far beyond national borders and have international teams of researchers engaged and sharing resources across many institutions and nations.

This aspect of innovation collaboration is another space where regional talents and assets intersect with global networks of expertise.

The Water for Food Institute

The Water for Food Institute was established in April 2010 at the University of Nebraska. The institute's mission is to conduct research, policy analysis and educational programs on the efficiency and sustainability of water use in agriculture, the quantity and quality of water resources, and the human issues that affect the water decision-making process.[10] Nebraska brings expertise and research experience to the issue as the most irrigated state in America, sitting on top of the Ogallala Aquifer, the largest freshwater resource in North America.[11]

"Using water efficiently in agriculture is critical to feeding the world," University of Nebraska President James B. Milliken says. "By 2050, the population of the world will increase from about 6.5 billion to more than 9 billion, requiring food production to double to meet this need. That has to happen with the same amount of water, or even less water, because as the population grows, urban centers require more water for sanitation, safe drinking and industrial uses. The potential partners for this work are spread across the world. [The] solutions may be different in Nebraska than they are in South Asia, for instance, but we believe that there are commonalities; that there are some policy issues; that there are some basic research issues that are important to both [areas]."[12]

The Water for Food Institute has already joined with a number of international partners, including the University of São Paulo, Brazil; Jain Irrigation Systems Ltd. in India; and the Food and Agriculture Organization in Italy.

10 Robert B. Daugherty Water for Food Institute. Overview. http://waterforfood.nebraska.edu/about-wfi.

11 Tan, Jaclyn. Water for Food Institute a Global Leader in Water, Food Research. http://liferaydemo.unl.edu/web/sdn/food_research 2011.

12 Ibid.

PART 1: PRE-REPORT FOR TLSI DIALOGUE 8

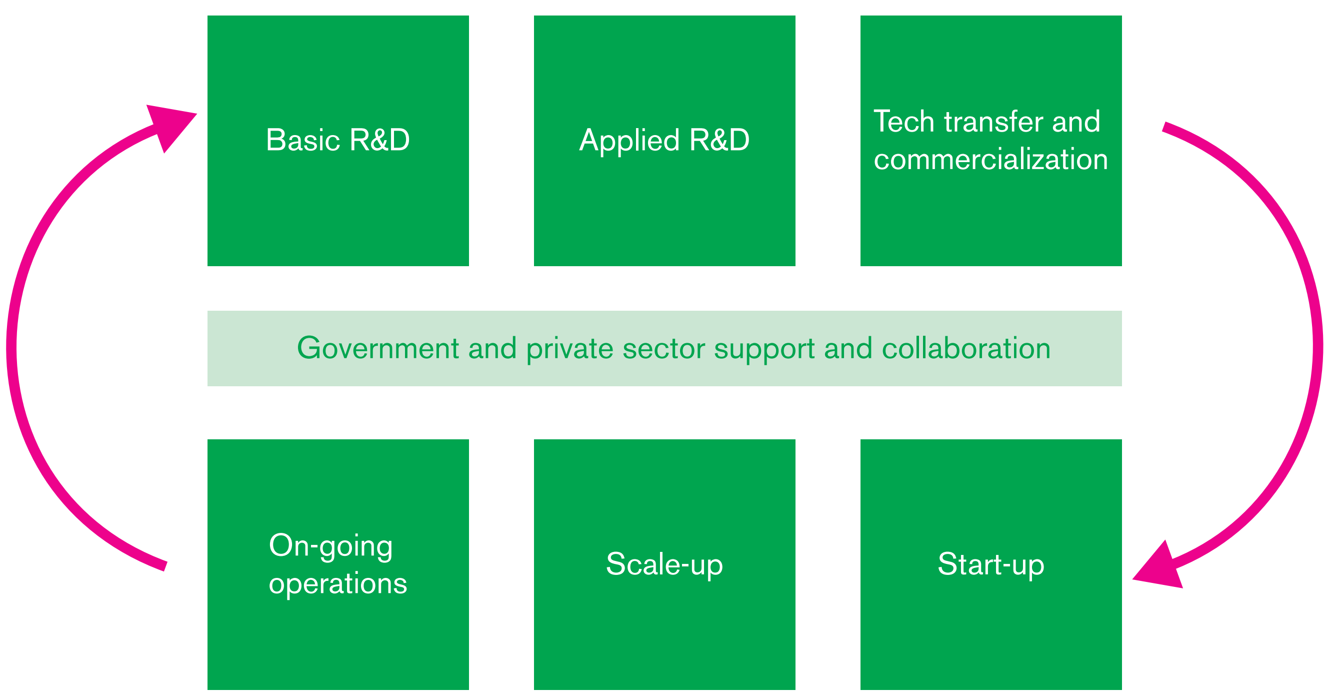
Integrating Modern Production Considerations into the Innovation Process

The Council's seminal report *Make: An American Manufacturing Movement* asserts that manufacturing business models evolved to consider production and innovation separately. Manufacturing was viewed as a cost to be minimized rather than a process to be optimized for competitive advantage. Conventional wisdom emerged that as long as high-value added work—e.g. engineering and design—remained in the United States, and government focused on small business, then the economy would grow and large-scale production could be left to its own devices. This model, however, is not sustainable.

The Council suggests that rather than assuming innovation and manufacturing processes should be linear and disconnected, the two should be integrated, creating a virtuous feedback cycle (Figure 8). *Make* notes that government policies and programs tend to focus on basic R&D, applied R&D, technology transfer, and early stage commercialization without a great deal of consideration about production at scale, in some ways encouraging an "invent here, make there" mentality for innovation.

Harvard Business School Professors Gary P. Pisano and Willy C. Shih build on this concept by asking when—or in what sectors—is manufacturing critical

Figure 8. Innovation and Manufacturing Lifecycle Illustration
Source: *Make: An American Manufacturing Movement*, Council on Competitiveness, 2011.



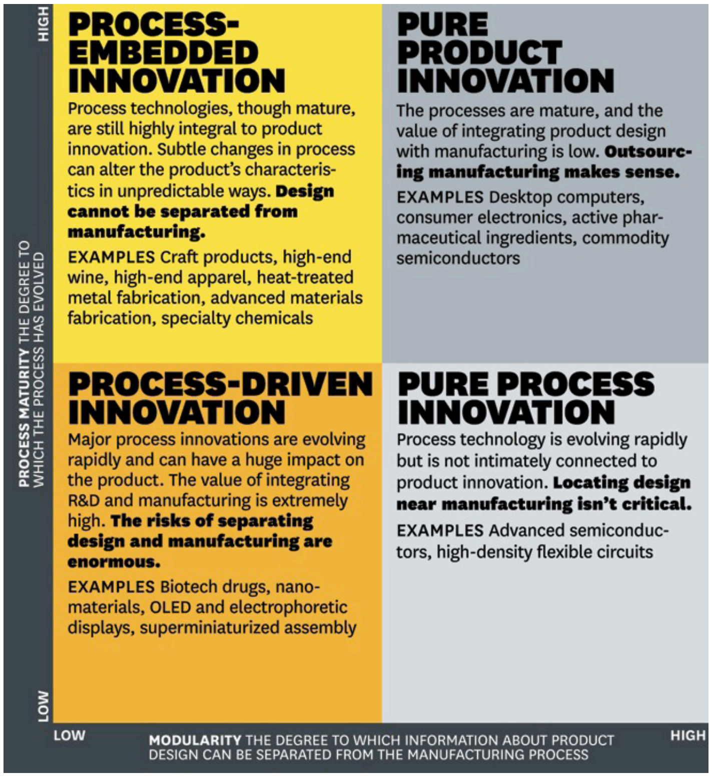
to innovation. "There is a large camp that contends that as long as Americans are doing the design and R&D (the high-value-added stuff), manufacturing is irrelevant…This line of thinking is based on false premises about the divisibility of R&D and manufacturing in the innovation process."[13]

The professors do not argue in their book that manufacturing and innovation are always intertwined. They suggest that the reliance is determined by (1) the degree of modularity, or ability of R&D and manufacturing to operate independently of each other, and (2) the maturity of the manufacturing process technology (Figure 9).

Using this matrix, the authors suggest that innovation/design should not be separated from manufacturing in areas such as advanced materials, specialty chemicals, biotechnology and pharmaceuticals, or organic light-emitting diode displays. In cases where production processes are mature or the process technology is not tightly linked to the product, co-location of research and manufacturing may not be important. This would apply to products like desktop computers, commodity semiconductors, or high-density flexible circuits.

Pisano and Shih note, however, that the need for proximity between R&D and manufacturing can be different for a final product and its individual components because they may fall into different quadrants of the modularity-maturity matrix. They cite the Apple iPad as an example, stating that the product "could be designed in California while many of its components are designed and produced in Asia, where final assembly also occurs. But a number of the

Figure 9. Modularity-Maturity Matrix
Source: Gary Pisano and Willy Shih



iPad's components (e.g. lithium ion batteries and the touch screen) fall into different quadrants, where it's important for R&D and manufacturing to be located near each other."

The authors follow this example with a warning about national or regional competitiveness, stating "the location of those R&D and manufacturing capabilities in other countries means that the future products that need those capabilities will come from those countries, too."

The interwoven dynamics of employment, output and productivity in high-technology manufacturing are complex. According to data compiled by the

13 Pisano, Gary P. and Shih, Willy C. Producing Prosperity, Why America Needs a Manufacturing Renaissance. Harvard Business Review Press, 2012.

National Science Foundation (NSF), "employment in U.S. high-technology manufacturing sectors reached a peak in 2000, just before the 8-month-long recession of 2001. This recession led to substantial and permanent job losses in these industries. The 18-month 2007–2009 recession further squeezed employment in these industries. The total job loss in high-technology manufacturing over the period was 687,000—a decline of 28 percent since 2000. The value of output generated by these industries contracted in 2001 and again slowed in 2007–2008. However, over the decade, output per 1,000 employees doubled (unadjusted for inflation)"[14] (Figure 10).

The NSF-assembled data is based on a definition of high-technology manufacturing sectors used by the OECD, which identifies high-technology industries largely by their level of research and development intensity (R&D investment in relation to value added). The data paint a reasonably good picture of what has transpired during the past decade in R&D intensive manufacturing industries (Figure 11).

Teasing out important causation and competitiveness questions from the data, however, is difficult. Would employment have suffered more without the productivity gains as industries became less competitive and possibly moved facilities out of the United States? What share of employment loss or manufacturing output is linked to greater offshore R&D activities? What share of job loss or output suffered is attributable to slower economic growth and global demand—independent of productivity or R&D location factors?

Ultimately, the question to be asked is: what is the best path forward to encourage increased innovation and manufacturing in the United States? What should be done by various stakeholders to create regional economies that attract investment, incubate new firms, partner strategically across the globe, and generate high employment rates and increase living standards?

Although corporate leaders must pursue what makes the most sense for their shareholders and the firm's success, they also typically seek to do well by the multiple places they call "home." These leaders tend to work actively to succeed in those regions where they have invested in people, plants and laboratories. They engage with local, state and federal policymakers; they partner with schools and universities; and like Frederick Taylor, they strive continuously to ensure that their operations are efficient and profitable.

Firms do not, however, operate in a vacuum. Whether large or small, companies are as successful as the talent they employ is skilled and creative. They are impacted by tax and regulatory policies, driven by market costs and conditions, reliant on public infrastructure, and often subject to strategic moves made by their global competitors. In such a dynamic environment, regional stakeholders and public policymakers are continually challenged to create favorable environments that maximize economic activity in the United States. Technology innovation and competitive advanced manufacturing lie at the center of this challenge.

14 National Science Foundation. Overview, High-Technology Manufacturing Employment. http://www.nsf.gov/statistics/seind12/c0/c0s11.htm.

Figure 10. U.S. High–Technology Manufacturing Employment, 2000-2010

Sources: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2011) of Bureau of Labor Statistics, Current Employment Survey

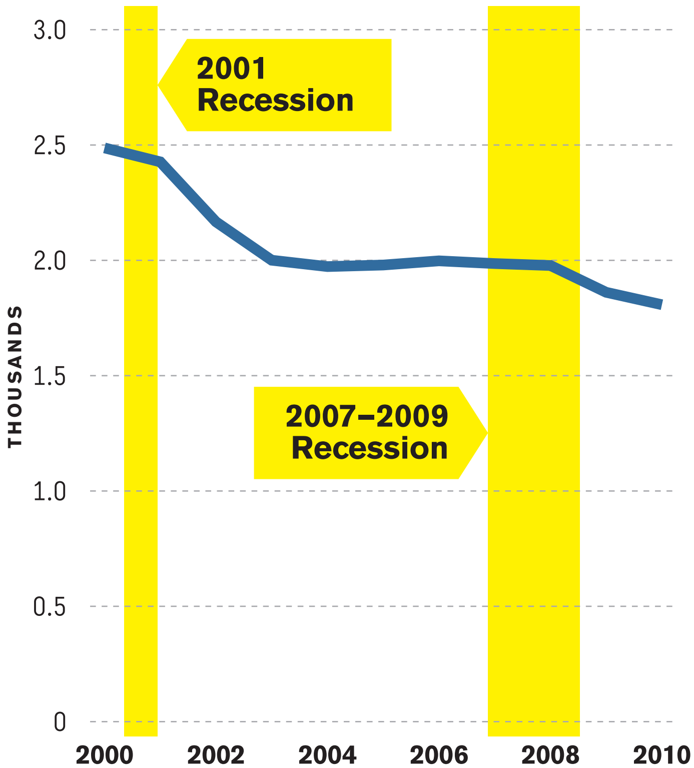
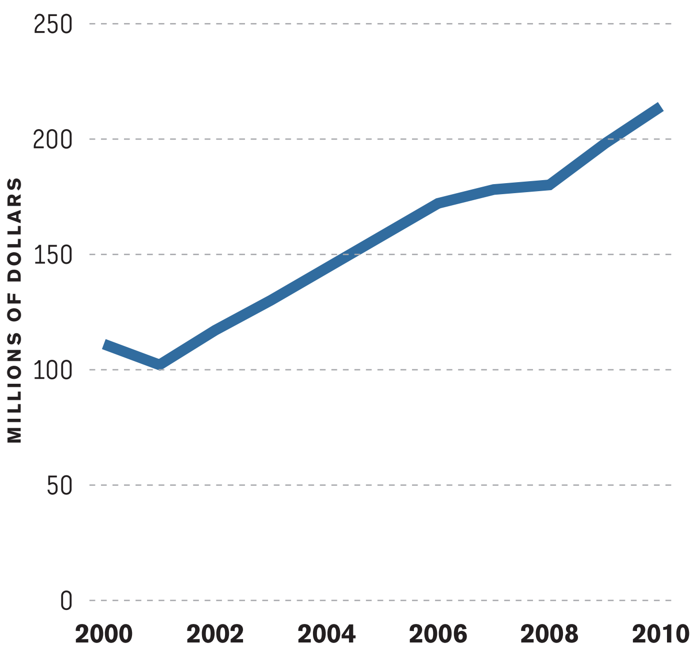


Figure 11. Value of U.S. High–Technology Manufacturing Output Per 1,000 Employees, 2000-2010

Sources: National Science Foundation, National Center for Science and Engineering Statistics, special tabulations (2011) of HIS Global Insight, World Industry Service database, and Bureau of Labor Statistics, Current Employment Survey.



NOTE: Industries defined by the Organisation for Economic Co-operation and Development (OECD).

PART 1: PRE-REPORT FOR TLSI DIALOGUE 8

Conclusion

Although the science of management has come a long way since Frederick Taylor rose to prominence a century ago, he opened the door to a larger scope of innovation—one that studied and experimented with management practices, labor productivity and business processes in addition to new technologies. Today, innovation pursued by organizations extends even further. Behavioral scientists and systems engineers, for example, delve into the science of design and services. Researchers seek to optimize not only the offerings and functions of their own organizations, but also those of external partner and supplier networks that can span the globe. The Council has promoted such innovation first hand through the National Digital Engineering and Manufacturing Consortium (NDEMC), where original equipment manufacturers work to extend the benefits of modeling and simulation to American companies in their supply chain.

TLSI Dialogue 8 will examine the issues outlined in this report—particularly emerging insights on the linkage between research and manufacturing, including leadership in strategic clean energy manufacturing. Participants also will explore the importance of global innovation networks to American competitiveness and consider new learning and knowledge management systems.

Taylor believed that scientific analysis could divine the optimal way to complete a task or manage an organization. The pace of innovation today means not only rapid product cycles, but also rapidly evolving production techniques, new materials, an explosion of available data, and new business models that leverage this change. Through the TLSI, the Council looks to illuminate these horizons and drive actions to accelerate technology commercialization, enable more effective partnerships, and solve technology grand challenges.

Part 2:
Findings from
TLSI Dialogue 8

PART 2: FINDINGS FROM TLSI DIALOGUE 8

Opening Remarks

The Honorable Deborah L. Wince-Smith, President and CEO of the Council on Competitiveness (Council), welcomed participants to the dialogue and thanked the co-chairs of the Technology Leadership and Strategy Initiative (TLSI)—Dr. Klaus Hoehn, Vice President for Advanced Technology and Engineering at Deere & Company, Dr. Ray O. Johnson, Senior Vice President and Chief Technology Officer of the Lockheed Martin Corporation, and Dr. Mark Little, Senior Vice President and Chief Technology Officer of the General Electric Company and Director of GE Global Research.

Ms. Wince-Smith also thanked Dr. Donald Leo, Vice President and Executive Director of National Capital Region Operations at Virginia Polytechnic Institute and State University (Virginia Tech), for hosting the dialogue. To the participants, she noted that "over the last four years we have made an impact on our nation's policymaking because of the commitment and intellectual firepower that we bring together in these dialogues."

She concluded by reviewing recent and upcoming Council activities, including a dialogue on energy, food and water issues; work related to high performance computing (HPC) supported by a new three-year United States Department of Energy (DOE) grant; dialogues across the country under the U.S. Manufacturing Competitiveness Initiative; and the inaugural National Competitiveness Forum.

In his opening remarks, Dr. Johnson noted that the TLSI has evolved into "a central hub" for Council activities in areas like manufacturing, energy and high performance computing because each initiative has a significant technology component. "Technology and engineering have been and will continue to be the cornerstone of innovation that drives economic progress and competitiveness in the world."

Dr. Ray Johnson, Lockheed Martin Corporation; the Honorable David T. Danielson, United States Department of Energy; the Honorable Deborah L. Wince-Smith, Council on Competitiveness; Dr. Mark Little, General Electric Company; and Mr. Chad Evans, Council on Competitiveness.

Another cornerstone for America, he noted, is the nation's "ability to embrace diversity and allow anyone with a good idea to create a vision, pursue funding, and build a company."

Dr. Johnson concluded by thanking TLSI members for their participation, reviewing the agenda, and illustrating the relevancy of TLSI issues in Washington, D.C. Dr. Johnson shared with TLSI participants thoughts from his testimony on August 1, 2012, before the Committee on Science, Space and Technology in the U.S. House of Representatives on the importance of collaboration between business and research universities. He also noted that the committee is examining regulatory burdens faced by research universities.

PART 2: FINDINGS FROM TLSI DIALOGUE 8

Virginia Tech Research Center

Dr. Leo welcomed TLSI Dialogue 8 participants and presented an overview of the new Virginia Tech Research Center in Arlington, Virginia, in operation since 2011. About 30 faculty and their graduate students conduct research at the Virginia Tech Research Center. The majority of Virginia Tech's 31,000 students are located on the main campus in Blacksburg, Virginia, with about 1,000 students located in six locations within the National Capital Region.

The research conducted at the Virginia Tech Research Center deals primarily with cybersecurity and decision informatics that utilize HPC modeling and simulation. Dr. Leo noted that the facility also houses the Virginia Tech Applied Research Corporation "to take our work in basic research and transition it into more applied research with different technology to customers," particularly in the defense and intelligence fields.

Dr. Leo concluded by noting the growing importance of partnerships to Virginia Tech, both as a way to better serve students and a way to grow a network of funding sources, especially in the face of a potentially changing federal research landscape. He noted a partnership with L3 Communications at the center and collaborations with venture capital (VC) groups. Virginia Tech also pursues other partnerships in advanced manufacturing through the Commonwealth Center for Advanced Manufacturing (CCAM), working with companies like Rolls-Royce, Siemens, Newport News Shipbuilding, and Canon.

Discussion

Ms. Wince-Smith thanked Dr. Leo for his remarks and complimented Virginia Tech and CCAM's innovative intellectual property (IP) model. At CCAM: generic "pre-competitive" research is shared by all CCAM members, whereas direct "competitive"

Dr. Donald Leo, Virginia Polytechnic Institute and State University.

research is solely funded and solely owned by one company.[15] "What you put together, co-created with partners, is one of the best models for intellectual property. Everyone wins and collaborations can move forward," continued Ms. Wince-Smith.

Dr. Johnson, too, applauded the efforts described by Dr. Leo and put forward three ideas that could help engineers become more effective and more able to contribute to U.S. competitiveness. First, an emphasis on interdisciplinary research enables students to understand how problems require broad expertise. Second, he supported placing emphasis on innovation rather than invention. "Engineering students generally have too little exposure to business. Exposure to real challenges like finance, marketing and contracts helps teach students to apply scientific methods to these problems as well as the technology issues." Finally, said Dr. Johnson, it is important to teach engineers to think about the challenges of manufacturing at scale.

15 Kranz, G. "Collaboration is the watchword at innovative research facility CCAM." Virginia Business.

PART 2: FINDINGS FROM TLSI DIALOGUE 8

New Collaboration and Partnership Models—Seizing the Clean Energy Manufacturing Opportunity

Similar to Virginia Tech's outreach, the Honorable David T. Danielson, Assistant Secretary for Energy Efficiency and Renewable Energy (EERE) of the U.S. Department of Energy, spoke with TLSI participants about reaching outside of the government for collaborations and partnerships through the Clean Energy Manufacturing Initiative (CEMI). Efforts within CEMI will focus on both the development of next generation products and systems like solar modules and batteries, and on improving the energy efficiency of all industries to "lower their energy cost and make them more competitive." To help carry out the initiative, EERE has created a new Advanced Manufacturing Office. The Advanced Manufacturing Office will fund six manufacturing demonstration facilities (Figure 12) over the next five years to tackle cross-cutting energy manufacturing challenges. Each facility is envisioned to be funded at approximately $50 million over five years, matched by a $50 million investment from the private sector.

Two manufacturing demonstration facilities have already been established at the Oak Ridge National Laboratory (ORNL), continued Dr. Danielson.[16] One facility focuses on "new formulations—new materials—that will lower the cost of carbon fiber, examine whether carbon fiber will work at scale, and raise sufficient capital to incorporate carbon fiber into a commercial facility." The other demonstration facility at ORNL focuses on additive manufacturing.

Dr. Danielson suggested that other facilities supported by the Advanced Manufacturing Office could center on low-cost, lightweight structures and on wide bandgap semiconductor devices that could drive the next generation of power electronics across several platforms.

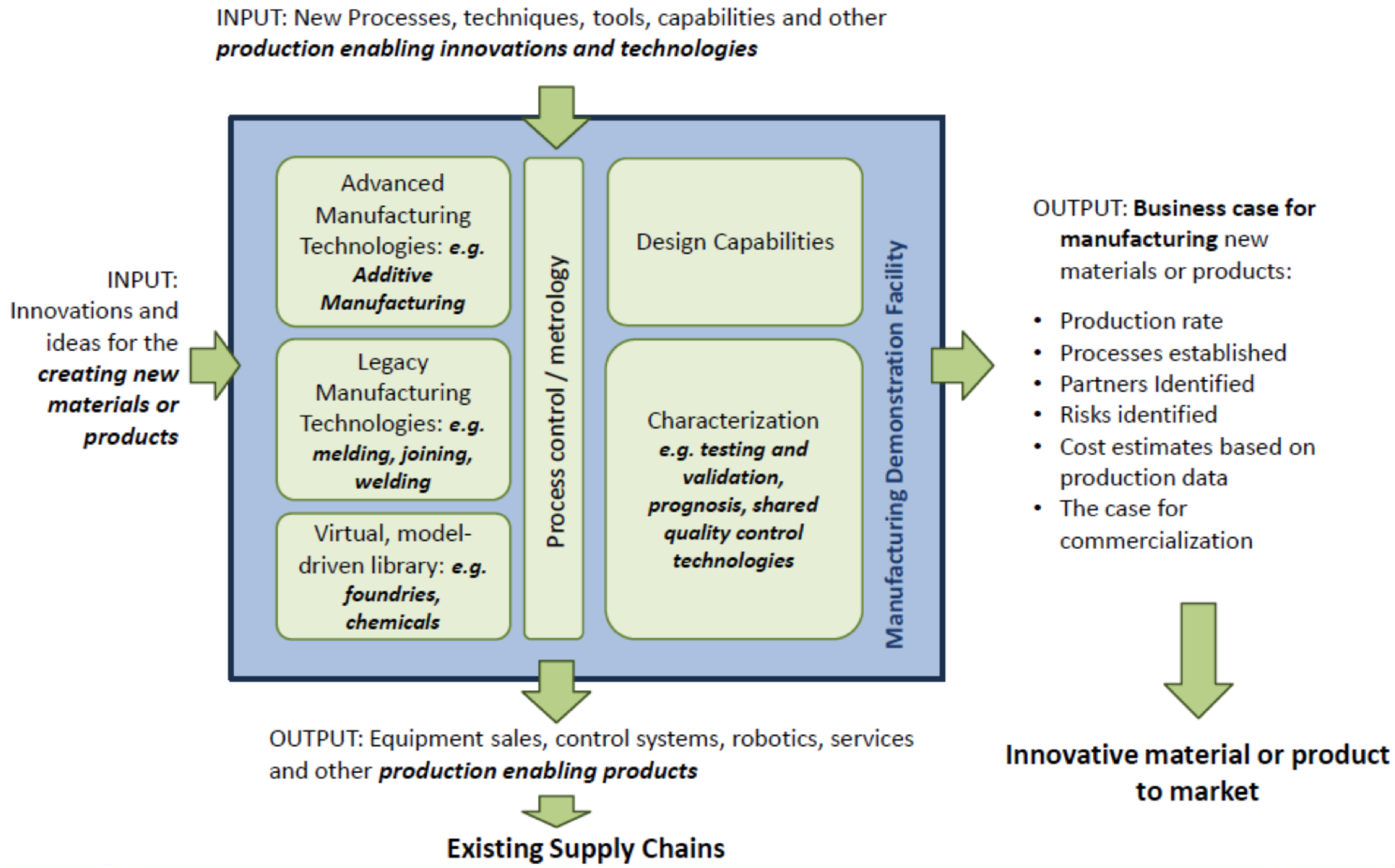
The Honorable David T. Danielson, United States Department of Energy.

Other EERE priorities include focusing each EERE program "on very application-specific problems that incorporate manufacturing competitiveness into program goals." Dr. Danielson said that future budget requests will seek new cross-program elements to achieve this goal.

EERE seeks to invest where the United States has a competitive advantage, so investment in "the private sector, universities and the national laboratories to make technology better and cheaper, is not immediately followed by overseas manufacturing of these products." To support this goal, the National Renewable Energy Laboratory (NREL) formed a research group to analyze clean energy manufacturing competitiveness.

16 More information on these two facilities is available at: http://www.ornl.gov/science-discovery/clean-energy/facilities-and-centers/carbon-fiber-technology-facility/carbon-fiber-technology-facility and http://www.ornl.gov/user-facilities/mdf.

Figure 12. Two Pathways through a Manufacturing Demonstration Facility
Source: U.S. Department of Energy, EERE



Dr. Danielson also discussed two energy grand challenge initiatives—the SunShot Challenge to add cost-competitive solar energy to the grid and the EV Everywhere Challenge to make plug-in electric vehicles as affordable and convenient as gasoline-powered vehicles by 2022.

Another EERE priority is integrating distributed renewable energy sources like wind and solar technologies onto the grid. "I am concerned that if we don't ensure that we have the right physical infrastructure on the grid and the right market structures for utilities … these will become barriers to growing that market." The DOE "is creating an agency-wide grid technology team to develop a coherent game plan. EERE will play a big role there, especially on the distribution side and behind the meter."

Dr. Danielson also previewed a new Technology-to-Market Initiative[17] to be launched in 2013. "The vision is to dramatically lower the friction and bridge the gaps in the U.S. energy innovation system and get more productive commercialization from our unique competitive advantages: a high quality R&D workforce, the most entrepreneurial market in the world, and phenomenal large companies. How can we become more competitive utilizing our ecosystem?"

He concluded by posing a few questions to the TLSI participants. "What are the high-impact issues that DOE should consider to help bolster U.S. competitiveness in clean energy manufacturing and advanced manufacturing generally? What are the gaps

Dr. Steven Ashby, Pacific Northwest National Laboratory; Dr. Tilak Agerwala, IBM; and Dr. Erik Straser, Mohr Davidow Ventures.

and opportunities? How can we create a competitive environment—where siting a factory in the United States is a rational decision?"

Discussion

Creating a Competitive Environment

Dr. Erik Straser, General Partner at Mohr Davidow Ventures responded to Dr. Danielson's questions by identifying two fundamental issues: crossing the valley of death and once across the valley of death, attracting companies to build manufacturing plants in the United States. In crossing the valley of death—building the first commercially viable production facility—Dr. Straser encouraged TLSI participants to consider "the mechanics and financial instruments that can help entrepreneurs make that happen." To help address the valley of death, Dr. Straser suggested ways to reduce the capital requirements of small or start-up producers. One suggestion was to

17 More information regarding the EERE Technology-to-Market Initiative available at: http://www1.eere.energy.gov/office_eere/sp_tech_market.html.

create a national inventory of manufacturing assets that could be used on a pay-per-use basis. Dr. Straser also proposed some form of public-private partnership to identify dormant, idle or under-utilized manufacturing assets within large companies that could be made available for new vendors or emergent manufacturers on terms beneficial to both parties.

"The second issue is the plant number two problem—an American competitiveness problem." Dr. Straser explained that investors, when building the first manufacturing plant, often want to locate it very close to the R&D facility, "because it makes sense—accelerating the learning cycle and having access to knowledgeable workforce. The first plant is a very large pilot line, where the firm and its investors are still learning its own technology and processes. As the business matures to the stage of building a second manufacturing plant, the site decision elevates to the level of the executive board. From the perspective of the executive board, considering market and labor forces, the list of best places to site this second plant does not include the United States."

Dr. Straser suggested that a set of commercial strategies oriented around young manufacturers is needed to encourage plant number two to be sited in the United States. Policies and incentives that would tip decisions towards the United States would be helpful, he said.

To these thoughts, Dr. Johnson added that competitive manufacturing in the United States for many businesses still requires finding ways to offset the labor cost advantage in other nations. He suggested that the incorporation of automation, digital design, and additive manufacturing could be part of the solution. Dr. Johnson also noted the importance of community colleges conferring skills relevant to local workforce needs.

Dr. Danielson agreed that community colleges offer great potential and added that TLSI members should consider an education model developed by Dr. Michael Crow, President of Arizona State University. He described the model as "a college of practice" where students are prepared to manufacture products immediately upon graduation.

Dr. John Parmentola, Senior Vice President for Energy and Advanced Concepts at General Atomics, stated that industry tends to be more engaged in research and commercialization supported by the U.S. Department of Defense (DOD) than in efforts supported by the DOE. He suggested partnership models for applied research projects where industry leads teams with university and national laboratory partners. Another example of DOD engagement, shared Dr. Parmentola, is the Army's creation of the private equity firm, OnPoint Technologies, to assist small innovative firms working on technologies that have both military and commercial potential.

Dr. Danielson indicated that greater industry partnerships represent an important opportunity. He would like to combine the innovative ideas generated typically by small companies, universities, and national laboratories with the deep market knowledge of larger firms. Dr. Danielson would like to introduce researchers to "high-impact applied problems of relevance to industry" in a way that maintains industry confidentiality. If that barrier could be addressed, he asserted, "we could make a lot of progress."

Dr. John Parmentola, General Atomics.

Dr. Steven Ashby, Deputy Director for Science and Technology at the Pacific Northwest National Laboratory, suggested that one way to increase industry partnerships with the national laboratories would be to broaden the number firms eligible to take advantage of the newly created Agreements for Commercializing Technology (ACT). Under current ACT rules, a firm (or other non-federal entity) may not access participating national laboratories through an ACT if any or all of the entity's funding originates from a federal source. No such restrictions exist under the Non-Federal Work for Others (NFWFO) mechanism or Cooperative Research and Development Agreements (CRADAs).

Dr. Ashby also encouraged Dr. Danielson to consider supporting a statutory reform that would grant national laboratories more flexibility to help firms cross the valley of death by easing the one-half percent limit on their base of funds available for technology transfer. Even raising the limit to one percent could help the national laboratories balance their basic research and technology maturation activities, suggested Dr. Ashby.

Mr. Thomas Halbouty, Vice President, Chief Information Officer and Chief Technology Officer for Pioneer National Resources, added that his firm is partnering with a national laboratory on computer aided design and manufacturing tools. He also raised a concern that although U.S. national laboratories create breakthroughs that few nations can match; competing nations are investing more heavily into manufacturing ecosystems that enable them to mass-produce those breakthroughs.

Mr. James Phillips, Chairman and Chief Executive Officer of NanoMech Inc., emphasized the importance of IP protection—"the most serious issue facing our company and other companies our size." He described the problem of IP theft as tougher than securing initial capital or crossing the valley of death.

Ms. Dona Crawford, Associate Director for Computation at Lawrence Livermore National Laboratory, urged increased leveraging of DOE's HPC assets for modeling and simulation. She explained that in some cases firms are not willing to make the initial investment in a partnership because the value proposition is unclear. She suggested the creation of a fund to kick-start such partnerships that is repaid by successful projects and therefore self-sustaining.

Dr. J. Michael McQuade, Senior Vice President for Science and Technology at United Technology Corporation, supported Ms. Crawford's suggestion and complimented efforts to integrate DOE funding streams through the DOE Energy Innovation Hubs.[18]

18 More information on the DOE Energy Innovation Hubs available at: http://energy.gov/science-innovation/innovation/hubs.

He also urged DOE to continue strengthening its efforts on industrial energy efficiency, noting that retrofitted or green field manufacturing facilities should be built not only for advanced manufacturing, but also for energy efficiency as a competitive advantage.

TLSI participants also debated how to reinvigorate engineering in the United States and apply that talent to clean energy manufacturing challenges. Participants discussed the creation of a National Engineering Foundation or having the DOE mimic engineering support offered by the DOD. Concerns were raised by several members, however, that without adequate funding—or public support driven by a sense of urgency to achieve a clear clean energy mission—that a government planned solution was unlikely.

Dr. Danielson concurred, expressing confidence in the private sector. "What we need is not a command and control economy but an economy where the government helps unlock the capability of the private sector." He noted that over the last 40 years the price of solar electricity has come down 99.3 percent and that rooftop solar technologies are about "a factor of three away from being directly cost competitive." Dr. Danielson stressed that the United States should be awake and ready to take advantage of a revolution over the next ten years in the deployment of solar power technology due to economic sensibilities—not subsidies. Several participants concurred with this sentiment, noting the high value of government investment in frontier research and talent development.

Metrics

Dr. Danielson thanked TLSI members for their suggestions related to domestic production and partnerships. He also pressed the group to suggest metrics to evaluate the impact of national laboratories on U.S. industrial competitiveness.

Mr. Thomas Halbouty, Pioneer Natural Resources, and Mr. James Phillips, NanoMech Inc.

In response, Dr. Ashby put forward two metrics—the number of spin-off companies created and the percentage of a national laboratory's IP portfolio that is deployed and generating revenue. During this discussion, Mr. Halbouty added that a metric related to producing new products at scale (whether through large or small firms) would be an important measure of competitive impact, because only one of twenty start-up organizations survives. Mr. Halbouty also emphasized that goods and services exports are an important measure of national wealth creation.

Dr. McQuade stated that a metric should be able to project the value content of production in the United States. He also cautioned against using job creation as a primary metric, noting that honest expectations should be established between investment and jobs. Mr. Halbouty agreed, stating that he believes jobs will come with increased economic activity and value creation, particularly through exporting industries.

PART 2: FINDINGS FROM TLSI DIALOGUE 8

New Ways to Access Innovation and Talent

Mr. Chad Evans, Executive Vice President at the Council, introduced Dr. Straser and Dr. Montgomery Alger, Vice President and Chief Technology Officer at Air Products and Chemicals, Inc. to open a conversation about innovation and talent during the dialogue.

New Engagement Model for Innovation

Dr. Straser began by describing how several forces have changed over the past five years leading to the connection of Fortune 500 firms and start-up companies earlier and deeper to bridge innovation and talent gaps. The changes include:

- Lower capital requirements for many companies to move from idea to product, driven primarily by commodity information technology and contract manufacturing;
- The rise of a "maker" culture and access to advanced production equipment like 3D printing; and
- An increasing capability to aggregate, analyze, and make decisions from large volumes of data about customers, supply lines and operations.

Dr. Straser relayed that several Fortune 500 firms that he works with are looking to access top start-up talent and disruptive ideas that tend to be more outcome oriented and connected to the external world. Traditional internal R&D efforts, he noted, tend to focus more on evolutionary innovation and are more budget oriented. There is a new openness to things that can disrupt an organization, said Dr. Straser, and a desire to "figure out how to adopt the best of it while protecting the existing business."

Start-up companies often are attracted to the larger firm's manufacturing and distribution capacity, as well as access to capital.

Standing: Dr. Erik Straser, Mohr Davidow Ventures.

Dr. Straser explained two traditional engagement models between large firms and start-up companies. In mergers and acquisitions, the larger firm buys an operating business or product line, typically in the form of a smaller firm that is over five years old. In corporate ventures, large firms invest in promising smaller companies that have a second generation or "beta" product or perhaps early sales, and are typically 3-5 years old.

What is changing, asserted Dr. Straser, is a greater interest in nascent firms less than three years old with disruptive technologies and business models. "There is an emergent class of financial institutional investors called micro VCs. They number about 10-20 today and most of them are focused on playing beneath the traditional venture capitalists." This "lower end" of the market is "absolutely strategic for a Fortune 500 firm."

These early start-up companies offer several advantages, continued Dr. Straser. They can help Fortune 500 firms address their top operating needs, such as a new solution or greater efficiency. By being one of the first firms to invest in such a start-up company, Fortune 500 firms gain the advantage of being able to influence the new firm's product development at much lower cost than by engaging a more mature firm.

Finally, engaging start-up companies early offers access to top talent on flexible terms that enable the Fortune 500 firms to gain critical technology. "The model looks more like catch and release," he explained. The early-stage entrepreneurs may or may not be a good fit within a larger corporate culture, but through a license partnering or acquisition model the Fortune 500 firm can engage top talent, be selective over time about who remains with the company, and capture the technology.

Dr. Straser emphasized that the start-up company in these cases should not be treated as a vendor. "There may be two or three people who are in the top two percent of the talent you have ever interacted with—they have an ability to change your business." As examples, Dr. Straser discussed how early start-up companies like CliQr, Xperscore, ARC Camera and NanoSatisfi are serving large companies.

Discussion

Dr. Melvin Bernstein, Senior Vice Provost for Research and Graduate Education at Northeastern University observed that in some cases universities act in a similar manner to early start-up companies as a source of talent and technology for larger entities. He noted the HPC center run jointly by five major research universities in Boston.[19] At the center, "there is an incredible amount of talent," said Dr. Bernstein. The center acts "as a consulting company where both faculty and students work on problems that either the government or industry brings."

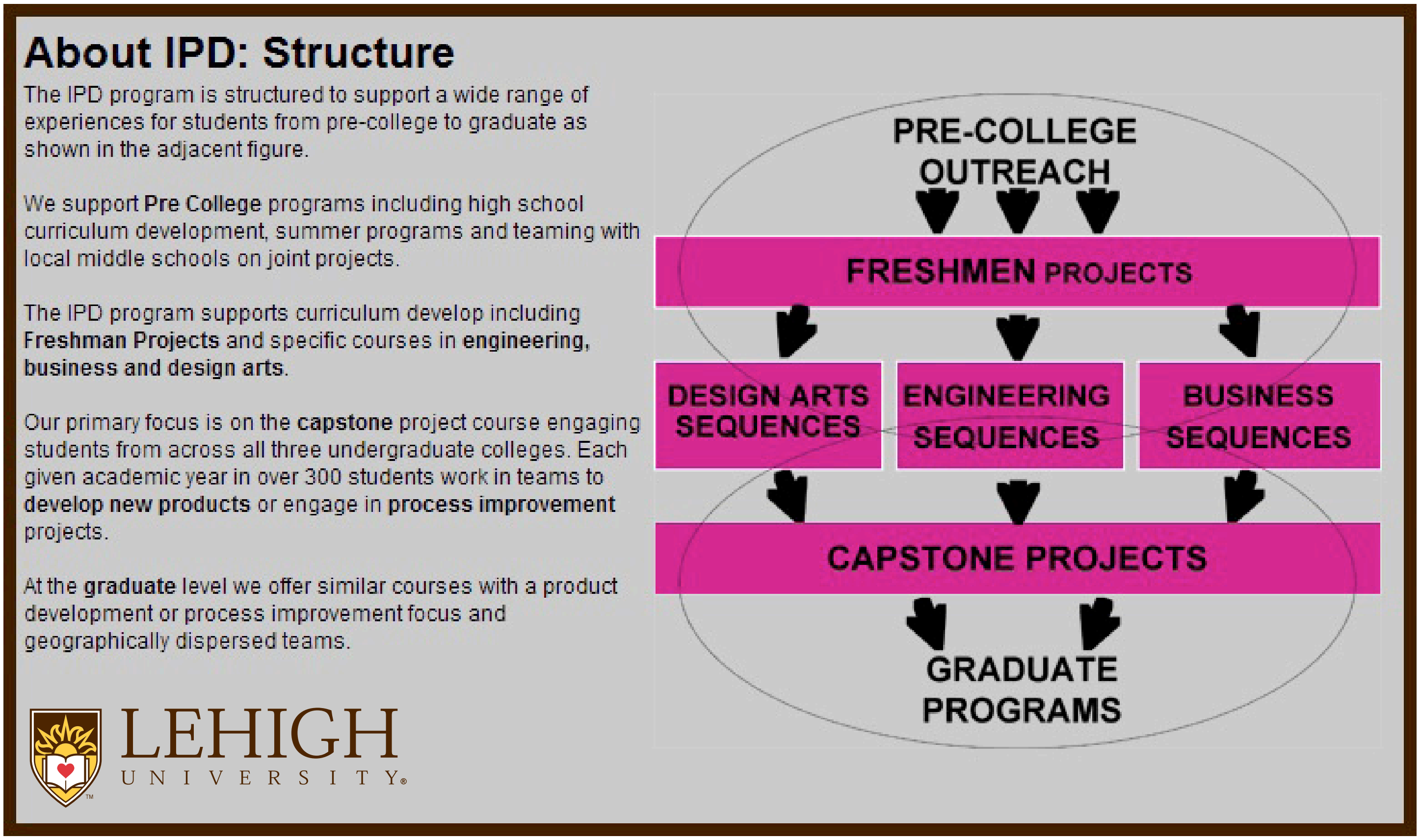
Dr. Straser agreed, and added that more schools are developing sophisticated entrepreneurship programs and adding executive education programs, centered on the idea that an entrepreneur could reconnect multiple times with a university over the course of a career to "refresh skills, gather new technology and go back out into the market."

TLSI participants asked Dr. Straser for his views on university IP management. Dr. Straser suggested that perhaps four or five American universities are state-of-the-art in negotiating with start-up companies and established firms. However, he explained that there is often a mismatch between the goals of a firm and a university. Once those mismatches are bridged, another mismatch often occurs between how each party values the IP in question. The entrepreneur or firm often has to acquire, license, or create several patents in order for the whole IP package to generate value, and it is often difficult to determine the royalty stream appropriate for each IP component.

The group also discussed efforts by universities to have their engineering and business schools interact. Dr. Straser suggested that it may take universities between ten to fifteen years to develop entrepreneurial cultures that enable such programs to thrive, sustained by experienced faculty members.

19 Massachusetts Green High-Performance Computing Center, a collaboration of universities: Boston University, Harvard University, Massachusetts Institute of Technology, Northeastern University, and the University of Massachusetts; industry: Cisco and EMC; and the Massachusetts state government. More information available at: http://www.mghpcc.org/.

Figure 13. Integrated Product Development Program
Source: Lehigh University



Dr. Alan Snyder, Vice President and Associate Provost for Research and Graduate Studies at Lehigh University, recalled a study about the motivations of faculty members involved in start-up businesses. The study found that about 17 percent of faculty members would be interested in staying with and growing a business—most wish to remain with the university.

Ms. Wince-Smith asked Dr. Snyder to describe the Integrative Product Development (IPD) Program (Figure 13) at Lehigh University. Dr. Snyder replied that the program assembles teams of engineering, business and design students at the undergraduate and graduate levels to take on real challenges, most of which come from industry. In addition to building the university's entrepreneurial ecosystem, said Dr. Snyder, the program helps many people within the university understand the outside world beyond the structure of federal grant programs that often shape academic projects and programs.

Innovation in Education

Dr. Alger led a discussion on emerging models for education and training, drawing a link between technology-aided instruction and partnerships between business, academia and government. He began with a story illustrating the vast amount of instructional knowledge available on YouTube and reviewed some of the initiatives to offer massive open online courses (MOOCs), such as edX, Coursera and the Khan Academy.

Dr. Alger illustrated how instructional videos from organizations like Khan Academy or the chemical engineering department of the University of Colorado are making content and teachers available to much wider audiences than in past years and cataloguing knowledge in an organized fashion. Learning about technology-aided instruction spurred thinking at Air Products and Chemicals, Inc. to apply this model for its business needs.

Dr. Montgomery Alger, Air Products and Chemicals, Inc.

"We have to find, hire, and train the next generation" around the world, explained Dr. Alger. He noted that even if retiring workers mentor new hires, the transfer of knowledge largely occurred at a local level. In rethinking knowledge transfer for the future, Air Products and Chemicals, Inc. analyzed key skills involved in building air separation plants, and believes that the functional skill areas fit into a knowledge map similar to the way the Khan Academy organizes content.

Air Products and Chemicals, Inc. is considering two paths to leverage this form of online learning. First, the company is exploring partnerships with other chemical firms to develop a common framework of learning that could be made available globally through online content and in partnership with universities. Right now, "the American Institute of Chemical Engineers is exploring methods to pilot this idea, getting multiple companies and universities working together to develop a framework," said Dr. Alger.

Second, companies could develop proprietary learning materials and videos to train new employees around the world, capturing the institutional knowledge of senior employees before they retire. "It is a way to inventory what is known, build upon it, and accomplish bigger and better things," stressed Dr. Alger. "We are looking at using technology-aided instruction more broadly—and not only for technical activities. We have a government contracting group and internal practices that we think will benefit."

Dr. Alger suggested using the TLSI as a platform to encourage funding mechanisms and partnerships between private and public institutions to advance these types of ideas with a good track record of improving educational outcomes. He also suggested that the online tools should integrate theoretical concepts with practical business applications—helping attract more students to engineering fields by enabling them to preview exciting things in the real world.

Discussion

Dr. Straser shared that the school system his children attend has adopted Khan Academy materials as part of their instruction. After about two years, early studies indicated that the top ten percent of students and the bottom 20-30 percent of students make meaningful improvement through the use of videos. The 50-60 percent of students between these poles perform similarly using the Khan Academy model or the older instructional model. Dr. Straser speculated that the impact might be similar in enterprise environments, helping top performers improve more rapidly and helping improve performance from lower achieving employees.

Dr. Alger shared a few observations he gleaned from conversations with younger engineers at Air Products and Chemicals, Inc. They confirmed that mentoring is an important part of how they learn and having a macro-level understanding of the company—"to see everything at once"—could be transformational. He noted that many companies lack portable teachers and that the Khan Academy model could help address the insights shared by the younger engineers.

Dr. Straser and Dr. Alger agreed that online learning could be applied more widely integrated into education for skilled labor like welders. Dr. Ravishankar Iyer, George and Ann Fisher Distinguished Professor of Electrical and Computer Engineering at the University of Illinois, Urbana-Champaign, interjected that the model requires a talented instructor able to convey difficult concepts clearly. He stressed that both the content and design of online instruction was critically important.

Dr. Ashby added a concern that an over-reliance on an online learning model might develop students who can apply existing knowledge but perhaps be less able to create new knowledge. Dr. Alger confirmed that a great deal of discussion centers on that concern. He and other TLSI members suggested, however, that well-run systems could use online tools to speed knowledge acquisition and free more time for problem solving and creative activities that help students think critically.

Dr. Straser concluded the conversation by suggesting that technology-enabled education models that make learning available to more Americans at a lower price point could help rebuild the country's middle class. He noted that more jobs will require higher education or skill levels than in the past and that more workers will need to continue building skills throughout their careers. Online learning models, while not a panacea, should help meet those needs.

PART 2: FINDINGS FROM TLSI DIALOGUE 8

Integrating Modern Production Considerations into the Innovation Process

Integrating in Industry

Dr. Ajay Malshe, Founder, Executive Vice President and Chief Technology Officer of NanoMech, Inc., opened the conversation on integrating modern production considerations into the innovation process by sharing insights he gained after deciding in 2002 to found a nanotechnology company. His first point of emphasis was to invest in people as a top priority to generate ideas and build an organization. He also emphasized the importance of "knowing what you don't know" so he could draw on the expertise of those more knowledgeable about positioning a product in the market or managing business processes.

Dr. Malshe reviewed several kinds of innovation in his remarks. He noted companies support innovations centered not only on new ideas, but also branding, efficiency, assembling technology, and manufacturing processes. "Nanotechnology and nano-manufacturing are the assembly of radical innovations." Dr. Malshe described two NanoMech, Inc. products to illustrate his point: a lubricant that extends the life of some steel parts by 1000 percent over current expectations, and a 15-micron coating for tungsten cutting tools that can extend their life in some cases by 950 percent.

Several ingredients are essential for research ideas to be translated into manufactured products, said Dr. Malshe. First, a high degree of trust is required between the stakeholders establishing the company. Second, the firm needs to nurture risk-takers to avoid becoming overly risk-averse as it grows larger. Dr. Malshe also emphasized the importance of capital and inventors that can see beyond the science to a product. The final element is perseverance. "I have failed many times but when the dust clears I look in the mirror and keep working."

The Honorable Deborah L. Wince-Smith, Council on Competitiveness and Dr. Ajay Malshe, NanoMech Inc.

Integrating in Universities

Following Dr. Malshe's remarks, Mr. Evans turned to Dr. Paul Hallacher, Director for Research Program Development at The Pennsylvania State University (Penn State). Dr. Hallacher also serves as the Director of Management and Administration of the Greater Philadelphia Innovation Cluster for Energy Efficient Buildings. Dr. Hallacher began by noting the diversity of post-secondary educational institutions. Because they have different core competencies, he cautioned against an overly simplistic generalization of the university role in technology commercialization and manufacturing. He also concurred with Dr. Malshe's emphasis on the critical nature of trust between university and industry partners.

Dr. Hallacher suggested that there are several common assumptions about technology commercialization, some of which he believes are true and some that are not completely true. His list of axioms included:

- Corporate research laboratories have largely disappeared and what is left focuses mainly on applied research with little or no corporate support for basic research;
- Patenting and licensing university technology is a way to create jobs and economic growth;
- Faculty and student spin-out companies are a vehicle to transfer technology held by the university;
- There is a valley of death where no money is available to bridge development between basic research and commercialization;
- University IP practices are major barriers to corporate research partnerships;
- University promotion and tenure policies support a culture of scholarly publication rather than one of commercialization and economic competitiveness;
- Companies within the same sector tend to co-locate within regional industry clusters;
- Technology transfer requires intermediaries between researchers and industry; and
- Education is too narrowly focused within disciplines and not sufficiently hands-on.

Dr. Hallacher led a discussion that either qualified or questioned these assumptions. He asserted that "patents and licenses are used to inhibit and create barriers to technology commercialization by industry as often, if not more, than they are used as vehicles for commercialization." He also noted that IP practices at universities and national laboratories are evolving in order to facilitate more partnerships with industry. He noted that Penn State recently scrapped its standard IP agreement in favor of a policy that grants IP derived from industry-funded research to the company that sponsored the research. Dr. Hallacher also noted the movement toward collaboration through DOE Energy Innovation Hubs, as mentioned previously by Dr. McQuade, and cited Obama Administration initiatives centered on energy and manufacturing.

Another cooperative effort gaining traction, observed Dr. Hallacher, is an industry-university research focus on supply chains and on helping supply chain manufacturers contribute to the innovation interests of original equipment manufacturers (OEMs).

> Science converts dollars to knowledge; engineering converts knowledge to product systems; and business converts products to dollars. That process is very important.
>
> **Dr. Ajay Malshe**
> NanoMech Inc.

The Honorable Deborah L. Wince-Smith, Council on Competitiveness; Dr. Mark Little, General Electric Company; and the Honorable David T. Danielson, United States Department of Energy.

Dr. Hallacher offered an alternative view to the assumption that companies within the same sector prefer to locate in the same region. “Industry does not tend to cluster regionally, even though there are some regional clusters in general.” He asserted that studies show that OEMs want to locate on the same continent as their major suppliers and customers, but that they don’t tend to cluster with competitors or cluster in sub-state regions with suppliers and customers. “The whole regional innovation cluster idea is debatable, based on the evidence,” he said.

Discussion

Mr. Halbouty and Dr. Malshe expanded on the concept of convergence, or assembling products from multiple patents. They suggested that greater cooperation across multiple universities might facilitate this kind of product development. Mr. Halbouty suggested that “getting friction out of the system” by easing IP hurdles could provide a catalyst. Dr. Hallacher believed the idea worth exploring, adding that, “we have spent more money protecting IP by far than we have earned from royalties—and the evidence is abundant.”

Dr. Ashby commented that many U.S.-based companies still struggle to engage American universities and some are looking to European universities for partnerships. Dr. Ashby prompted others to consider how much improvement is being made in university IP practices to encourage more partnership and commercialization.

Dr. Hallacher noted the difference in engagement culture between medical sciences and physical sciences and engineering and reiterated Penn State’s new commercialization outlook. Dr. Parmentola noted that data on the return on investment in university

research from IP and commercialization remains poor. He noted a program at the University of Colorado, however, made significant strides by building a community of local entrepreneurs. Dr. Iyer added that the University of Illinois is making strides to speed IP negotiations with industry.

Dr. Little offered a broad perspective to the dialogue from his experience with General Electric Company. "My experience shows that this mindset is changing very fast. There was a long dead period for GE where we were not connecting with universities on significant IP but the landscape is changing." Dr. McQuade stated that United Technologies Corporation does a lot of university-based research, but that is still a small share compared to research done internally. He also added, "The single most important piece of IP that comes out of universities is the one that you don't protect—and that is the employee that I hire." He asserted that university talent development was "infinitely more valuable than any IP that a university might try to protect and sell to me."

Ms. Wince-Smith introduced another topic into the conversation by questioning whether U.S. budget constraints open a competitiveness concern related to research and innovation. She asked, "What are we going to do when Chinese companies start coming in with massive amounts of money to invest in U.S. universities in critical areas?" She cited cybersecurity and supercomputing as examples. Dr. Malshe agreed with this concern, noting that when Chinese investors purchased A123 Systems, they obtained an IP portfolio that was funded in large measure by U.S. taxpayers.

Dr. Parmentola added that the multiplier used by Congress to fund research at "zero percent real growth" is outdated due to the complexity, manpower and equipment needs of modern research. Because of this, the buying power of federal research dollars has been declining. Other TLSI members expressed concern about research funding levels.

The single most important piece of IP that comes out of universities is the one that you don't protect—and that is the employee that I hire.

Dr. J. Michael McQuade
United Technologies Corporation

Dr. Straser asked whether the problem stemmed from a lack of a call-to-action that would pull together a critical mass of political will. Dr. Bernstein reviewed the call-to-action to double physical science and engineering budgets that stemmed from efforts by the Council and others to drive innovation growth. Although the doubling path was followed for about four years, Ms. Wince-Smith reminded members that a failure to get control of entitlement growth and U.S. debt has been the primary culprit for squeezing key discretionary budgets like research. Dr. McQuade added that in the current budget environment, asking for greater research investment also will require a conversation about greater efficiency in the research enterprise and rapidly rising cost to attend universities generally.

PART 2: FINDINGS FROM TLSI DIALOGUE 8

High Performance Computing Initiative Update

To begin the session on High Performance Computing, Mr. Evans introduced Dr. McQuade and Ms. Crawford, co-chairs of the Council's High Performance Computing Advisory Committee (HPCAC). Ms. Crawford opened by briefly describing the purpose of the HPCAC. "We support the use of HPC as a competitiveness engine for U.S. industries. We have a lot invested in our universities and national laboratories in HPC and we want to make sure that it is available for our industrial sector."

Ms. Crawford and Dr. McQuade then outlined some of HPCAC's guiding principles that would be refined at a December 2012 meeting. The principles were:

- Broaden the base of U.S. manufacturers using HPC-driven modeling and simulation—in many cases by driving the capability down OEM supply chains;
- Ensure that industry has knowledge of and access to HPC capabilities and applications; and
- Advocate for extreme computing by advancing hardware and software at the cutting-edge, eventually leading to exascale computing.

Ms. Crawford shared that the Council had been awarded a three-year grant from the DOE on extreme computing. The grant supports convening national leaders through the HPCAC, assessing the industrial applications of exascale computing, and making the business case for an exascale economy. Dr. McQuade added that the Council also has helped advise Congress about legislation to reauthorize the High Performance Computing Revitalization Act.[20]

The Honorable Deborah L. Wince-Smith, Council on Competitiveness and Ms. Dona Crawford, Lawrence Livermore National Laboratory.

Discussion

In the ensuing discussion, Dr. Johnson asked Dr. McQuade and Ms. Crawford whether the HPCAC seeks to extend HPC use widely for business purposes, including non-manufacturing applications like drug discovery and other knowledge-intensive activities. Dr. Johnson noted that while he supports efforts to develop exascale computing, "there are hundreds of other classes of problems that need solutions that can be approached using existing HPC capabilities."

The co-chairs confirmed that HPCAC is looking to broaden HPC use widely among companies and agreed with Dr. Johnson—firms have many problems that could be tackled by existing peta-scale HPC machines. Ms. Crawford emphasized that the biggest current challenge is less about having big machines

20 More information available at: thomas.loc.gov/cgi-bin/query/z?c109:H.R.28:.

than using computers more effectively for America's national security and economic competitiveness. She noted that the HPCAC is examining the independent software vendor (ISV) market as part of this challenge. "This is really about accessing HPC software and expertise and utilizing HPC systems to make a difference on somebody's bottom line," said Ms. Crawford.

Dr. Tilak Agerwala, Vice President for Systems at IBM, reminded the group that HPC is also important to solve big data challenges. "Big data challenges increases the relevance of HPC to a variety of different areas," he stated.

Dr. Ashby agreed that existing HPC capacity is underutilized and that the ISV market is perceived by many as an impediment to greater use of HPC. He also shared a sentiment from the prior HPCAC meeting—the United States does not have a clear strategy for exascale computing or consensus that it should be a funding priority.

As an example of broader uses of HPC, Dr. Cynthia McIntyre and Mr. Jack McDougle, Senior Vice Presidents with the Council updated TLSI participants about the National Digital Engineering and Manufacturing Consortia (NDEMC). Dr. McIntyre noted some of the successes of the Midwest pilot program in bringing modeling and simulation capabilities to smaller companies. NDEMC, supported by the Economic Development Administration at the Department of Commerce, may expand outside of the Midwest to other regions of the United States, she indicated.

Dr. Mark Little, General Electric Company and Dr. J. Michael McQuade, United Technologies Corporation.

Mr. McDougle emphasized that NDEMC stakeholders hope to determine a viable private sector business model to expand access to HPC modeling and simulation capabilities. He indicated that an industrial-based investment fund to continue some of the NDEMC projects could be an early piece of the puzzle. Dr. McQuade agreed, adding that the second phase of the pilot program will test charging fees for services to further shed light on potential business models.

PART 2: FINDINGS FROM TLSI DIALOGUE 8

United States Department of Defense Research and Development Priorities

Mr. Evans introduced Dr. Reginald Brothers, Deputy Assistant Secretary for Research at the DOD. Mr. Evans noted the strong relationship between the TLSI and the DOD, and how research and development conducted for commercial and security purposes are often mutually supportive.

Dr. Brothers outlined three major priority areas for DOD research and development.

The first priority centers on implementing new innovation models. Dr. Brothers discussed Trinity Spectre, a Special Forces exercise that takes place every year to bring together operators and developers over a period of two weeks to understand and operate through a scenario. During this exercise, developers gain a better understanding of scenarios and operational frameworks while operators gain insight on new capabilities. Dr. Brothers described this model as similar to user-producer innovation models where customers help shape products that enter the market or become producers themselves to meet their needs. Another new innovation model he noted was "open innovation," utilizing crowd-sourcing or source boards to solve problems.

The second priority is about the convergence of different areas of science and technology. Dr. Brothers identified three areas of convergence: (1) electronic warfare and cyber warfare, (2) quantum mechanics and quantum information systems, and (3) synthetic biology and nanotechnology. The DOD believes that these areas could have important defense implications. Dr. Brothers also discussed the importance of convergence between scientific and business disciplines in order to leverage a greater share of research and development into products and systems.

Dr. Nicholas Stone, Virginia Polytechnic Institute and State University; Dr. Paul Hallacher, The Pennsylvania State University; Dr. Alan Snyder, Lehigh University; and Vice Admiral Alfred Harms, Jr., University of Central Florida.

The third priority is how the DOD should best leverage the science and technology ecosystem—industry, universities and laboratories—now that a great deal of high impact science takes place outside of the defense environment. Dr. Brothers emphasized that the DOD will need new ways to interact with non-traditional actors, for example, through the use of challenge competitions.

Discussion

Transitioning this session to open discussion, Dr. Alger observed that across innovation ecosystems, there tends to be significant people and resources devoted to either basic science or to commercialization activities. People and resources are often missing in the middle—where great ideas connect to opportunities. "We have two stranded islands … and if you look at the history of big innovation, connecting people is the most valuable step." Dr. Snyder agreed, suggesting that challenge competitions in this middle area, created to connect ideas with applications, could be fruitful. Dr. Brothers agreed, but noted that IP issues could be a stumbling block.

TLSI participants also raised issues around factoring required time into innovation management so short-term security needs can be addressed while still devoting resources to game-changing long-term opportunities.

Another issue raised was whether the United States over-invests in invention rather than production capacity. In comparison, Japan and China were noted as nations that invest in the ability to scale inventions competitively regardless of the invention's country of origin. During this discussion Mr. Halbouty emphasized that the United States should invest more in scaling production and generating exports. These activities create national wealth that is critical for America's future.

PART 2: FINDINGS FROM TLSI DIALOGUE 8

Closing Remarks

Dr. Johnson and Dr. Little closed by thanking participants and noting the quality of ideas generated by the discussion. Ms. Wince-Smith offered a quote from former Texas Governor Oran Roberts:

> *National greatness is homemade. A homemade material is not exotic. It is not imported but produced and reared on the soil that it ennobles.*

The TLSI, said Ms. Wince-Smith, is fertilizing that soil for growth.

Dr. Ray O. Johnson, Lockheed Martin Corporation

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