American Energy & Manufacturing Competitiveness Partnership

Systemize.

Accelerating Advanced Materials Manufacturing

Compete.

Council on Competitiveness

Systemize: Accelerating Advanced Materials Manufacturing

THE COUNCIL ON COMPETITIVENESS is a nonprofit, 501(c) (3) organization as recognized by the U.S. Internal Revenue Service. The Council's activities are funded by contributions from its members, foundations, and project contributions. To learn more about the Council on Competitiveness, visit our home page at Compete.org.

Printed in the United States of America

American Energy & Manufacturing Competitiveness Partnership

Systemize.

Accelerating Advanced Materials Manufacturing

Table of Contents

Executive Summary

Over the course of 2015, the Council on Competitiveness (Council), the U.S. Department of Energy Offices of Fossil Energy (FE) and Energy Efficiency and Renewable Energy (EERE), the National Energy Technology Laboratory (NETL), and partners across the nation co-hosted the sixth, seventh and eighth American Energy & Manufacturing Competitiveness (AEMC) Partnership dialogues—a series of conversations specifically focused on accelerating advanced materials manufacturing. These dialogues continue a progressive dialogue series convened as part of the AEMC Partnership—a three-year effort between the Council and EERE to bolster American competitiveness through advanced clean energy manufacturing and increased energy productivity, and to address the dynamic changes affecting the national and global energy landscape.

During the 2013 and 2014 activities of the AEMC Partnership—spanning five dialogues and two annual AEMC Summits to date—national leaders from across industry, academia, labor, national laboratories, and other critical stakeholders have consistently emphasized the importance of developing, manufacturing, and deploying advanced materials as a critical leverage point with the potential to unleash a U.S. manufacturing renaissance by creating the conditions in this country to promote the adoption of clean energy technologies, and deeper investment in energy technology manufacturing. The three dialogues explicitly advance the conversation from the earlier and broader discussions around bridging individual organizations in the innovation ecosystem and the benefits of public-private partnerships—to focus attention on the critical leverage point and cross-cutting potential of advanced materials.

The Council and FE launched this targeted series of discussions in 2015—spanning the United States from Portland, Oregon, to Chicago, Illinois, to College Station, Texas—around accelerating the development, deployment, and diffusion of advanced materials into the manufactured marketplace and the wider economy. These AEMC Partnership Dialogues gather leaders from industry, academia, non-profit organizations, and the national laboratory system to discuss specific barriers and opportunities in developing, manufacturing, and deploying advanced materials to increase U.S. clean energy manufacturing competitiveness.

AEMC Partnership Dialogues 6-8 are another step in the ongoing conversation around increased U.S. energy, manufacturing, and economic competitiveness, and leads into the 2015 AEMC Summit in Washington, D.C. on September 16th.

The American Energy and Manufacturing Competitiveness (AEMC) Partnership Overview

The AEMC Partnership is a 3-year effort by the Council and EERE to bring together national leaders to address a rapidly shifting energy and manufacturing landscape. In a series of progressive dialogues since 2013, participants have considered actions that can be taken now to bolster American competitiveness in these areas. This is an effort formed under the DOE Clean Energy Manufacturing Initiative—a strategic integration of and commitment to manufacturing efforts focusing on American competitiveness in clean energy manufacturing. The goals of the CEMI and AEMC Partnership are to:

- **Increase U.S. competitiveness in the production of clean energy products:** Strategically investing in technologies that leverage American competitive advantages and overcome competitive disadvantages and
- **Increase U.S. manufacturing competitiveness across the board by increasing energy productivity:** Strategically investing in technologies and practices to enable U.S. manufacturers to increase their competitiveness through energy efficiency, combined heat and power, and taking advantage of low-cost, domestic energy sources.

The AEMC Partnership is broadly divided into two phases, "mapping the landscape" and the AEMC Partnership progressive dialogue series.

Phase One: Mapping the Landscape

To cultivate topics for the progressive dialogue series, and to provide a foundation for the larger goals of the AEMC Partnership, the Council performed an extensive literature review and mapped 184 past and current research efforts across the United States and around the globe concerning three core topics:

- Linkages between manufacturer efforts in energy efficiency and renewable energy and manufacturing competitiveness;
- Energy-related barriers to manufacturing competitiveness; and
- Models for PPPs for fostering competitive industries.

The literature review is documented in the Council publication, *The Power of Partnerships*, and its companion piece, *A Summary of Public-Private Partnerships*.[1]

Phase Two: The AEMC Partnership Progressive Dialogue Series

The second phase of the AEMC Partnership includes a total of five progressive dialogues in 2013 and 2014, leading into AEMC Partnership *Materials Manufacturing Accelerator* Dialogue 1, in which participants generate new insights pertaining to the overall goals of the AEMC Partnership, as well as inform the creation of a public-private partnership concept to further advance the initiative's goals.

1 These documents are available at http://www.compete.org/about-us/initiatives/aemcp/.

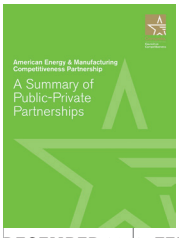
Reviewing Previous AEMC Partnership Dialogues

Inaugural Dialogue: Launch

The inaugural dialogue in Washington, D.C. on April 11-12, 2013, hosted by Mr. James Clifton, Chairman and CEO of Gallup, Inc., laid out the objectives of the AEMC Partnership, and began the process of closely examining a range of PPP model types and technology areas, drawing on the real-world experience, insights, and knowledge of leaders and practitioners from across a range of stakeholders—including government, industry, academia, labor and the national laboratories.

AEMC Partnership Dialogue 1, Washington, D.C.

The Honorable David T. Danielson, Assistant Secretary for Energy Efficiency and Renewable Energy, U.S. Department of Energy; the Honorable Deborah L. Wince-Smith, President & CEO, Council on Competitiveness; Mr. Jason Miller, Special Assistant to the President for Manufacturing Policy, National Economic Council; Ms. Elizabeth Wayman, Director, Clean Energy Manufacturing Initiative, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy; and Mr. Chad Evans, Executive Vice President, Council on Competitiveness.



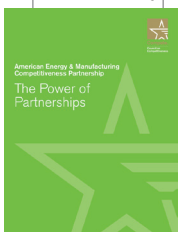
DECEMBER 2012–FEBRUARY 2013
AEMC Partnership Phase 1: Survey and Research
Research Conducted by the Council on Competitiveness

APRIL 11-12, 2013
AEMC Partnership Inaugural Dialogue: Launch
Co-hosted by Gallup
Washington, D.C.

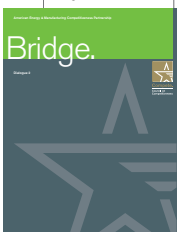
AUGUST 12-13
AEMC Partnership Dialogue 3: Evaluate
Co-hosted by General Electric
Niskayuna, NY

2012 2013

MARCH 26, 2013
AEMC Partnership Announcement
Co-hosted by Oak Ridge National Laboratory



JUNE 20, 2013
AEMC Partnership Dialogue 2: Bridge
Co-hosted by the University of Toledo, OH



OCTOBER 17, 2013
AEMC Partnership Dialogue 4: Focus
Co-hosted by Applied Materials, Inc.
Santa Clara, CA

Dialogue 2: Bridge

President Lloyd Jacobs of the University of Toledo hosted the second dialogue on June 20th, continuing the discussions sparked during the inaugural dialogue. This dialogue focused on Toledo as a case-study for successful informal and formal partnerships that can drive regional manufacturing transformation, in this case by leveraging materials science and engineering.

AEMC Partnership Dialogue 2, Toledo, OH

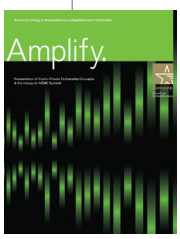
Dr. Jay Kim, Director, School of Dynamic Systems, University of Cincinnati; Mr. Lorry Wagner, President, Lake Erie Energy Development Corporation; the Honorable Deborah L. Wince- Smith, President & CEO, Council on Competitiveness; Dr. Lloyd A. Jacobs, President, The University of Toledo; and the Honorable David T. Danielson, Assistant Secretary of Energy Efficiency and Renewable Energy, U.S. Department of Energy.

NOVEMBER 2013
PPP Concept Leadership Survey
Survey and Research
Conducted by the Council on Competitiveness

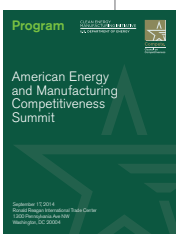
APRIL 16, 2014
AEMC Partnership Dialogue 5: Detail
Co-hosted by University of California, Berkeley
Berkeley, CA

2014

DECEMBER 12, 2013
Inaugural AEMC Summit: Amplify
Washington, D.C.



SEPTEMBER 17, 2014
2014 AEMC Summit
Washington, D.C.



Dialogue 3: Evaluate

Dr. Mark Little, Senior Vice President and Chief Technology Officer of GE and Director of the GE Global Research Center at the GE Global Research Center in Niskayuna, New York, hosted the third dialogue at the GE Global Research Center in Niskayuna, New York. The Council and EERE presented five specific PPP concepts for dialogue participants to discuss and critique around the major themes of leveraging national laboratories for manufacturing competitiveness, facilitating the scaling of innovative technologies to mass-manufacturing in the United States, and bringing public and private sectors together to accelerate the development and deployment of advanced materials in supply chains.

AEMC Partnership Dialogue 3, Niskayuna, NY

Mr. Chad Evans, Executive Vice President, Council on Competitiveness; the Honorable Paul Tonko, U.S. House of Representatives; the Honorable Deborah L. Wince-Smith, President and CEO, Council on Competitiveness; the Honorable David T. Danielson, Assistant Secretary for Energy Efficiency and Renewable Energy, U.S. Department of Energy; Ms. Elizabeth Wayman, Director, Clean Energy Manufacturing Initiative, Office of Energy Efficiency & Renewable Energy, U.S. Department of Energy; Ms. Jetta Wong, Deputy Director, Clean Energy Manufacturing Initiative, Office of Energy Efficiency & Renewable Energy, U.S. Department of Energy; and Dr. Mark Little, Senior Vice President and Chief Technology Officer, General Electric and Director, GE Global Research.

2015

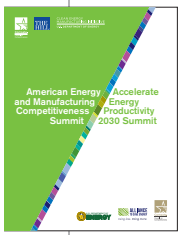
MAY 8, 2015
AEMC Partnership Dialogue 6
Co-hosted by National Energy Technology Laboratory and Oregon State University
Portland, OR

JULY 24, 2015
AEMC Partnership Dialogue 8
Co-hosted by Texas A&M University
College Station, TX

NOVEMBER 2015
AEMC Partnership Dialogue 9
Boston, MA

JUNE 16, 2015
AEMC Partnership Dialogue 7
Co-hosted by Argonne National Laboratory
Chicago, IL

SEPTEMBER 15-16, 2015
2015 AEMC Summit
Washington, D.C.



AEMC Partnership Dialogue 4, Santa Clara, CA

Mr. Michael R. Splinter, Executive Chairman of the Board, Applied Materials, Inc. and the Honorable Deborah L. Wince-Smith, President and CEO, Council on Competitiveness.

Dialogue 4: Focus

Mr. Michael Splinter, Executive Chairman of the Board of Directors of Applied Materials, and Dr. Omkaram Nalamasu, Chief Technology Officer of Applied Materials, hosted the fourth dialogue that focused squarely on evaluating two PPP concepts and honing the attributes of a clean energy manufacturing public-private partnership:

- Lowering risk and accelerating the adoption of advanced materials in the clean energy space through materials characterization, quantification, and standards development, and
- Lowering barriers to the scaling of existing, promising prototypes in the clean energy space by placing strategic resources on both sides of the scale-up "valley of death."

Dialogue 5: Strengthen

Dr. Nicholas Dirks, Chancellor of The University of California, Berkeley hosted the fifth dialogue on the university campus, where the Council and EERE presented a case-study of one tool-based PPP centered around increasing awareness and access to advanced computing resources. Discussions during the fifth dialogue supported the mutual benefit of partnerships to organizations across the ecosystem, when aligned around a need such as materials characterization or manufacturing optimization or around streamlined access to a tool, such as advanced computing resources.

AEMC Partnership Dialogue 5, Berkeley, CA

Top: *The Honorable Jennifer M. Granholm, Former Governor and Distinguished Practitioner of Law and Public Policy, University of California, Berkeley and The Honorable Deborah L. Wince-Smith, President and CEO, Council on Competitiveness.*

Bottom: *Dr. Nicholas Dirks, Chancellor, University of California, Berkeley, the Honorable David T. Danielson, Assistant Secretary for Energy Efficiency and Renewable Energy, U.S. Department of Energy, and Dr. Jon Schaeffer, Senior Engineering Manager, GE Power & Water.*

Setting the Stage for AEMC Partnership Dialogues 6–8

Advanced materials can drive significant enhancements in products and the economy by increasing the efficiency and optimizing energy products. Moreover, material technologies have the ability to increase the competitiveness of all manufacturing sectors, for example through broadly applicable advances in heat recovery processes, lubricants that reduce wear and on process equipment, and shaping processes that reduce material waste. As such, materials science and engineering have remained a central leverage point capable of meeting the goals of the AEMC Partnership.

Building a program around accelerating the development, manufacture, and deployment of advanced materials also helps address three specific manufacturing barriers that inhibit dramatic progress in clean energy manufacturing: insufficient access to capital, technical uncertainties from technical risk and imperfect information, and insufficient access to innovation infrastructure.[2]

2 The Council identified and documented twenty unique manufacturing barriers in the Power of Partnerships during Phase One of the AEMC Partnership. During Phase Two of the AEMC Partnership, regional and national clean energy manufacturing stakeholders from the public and private sectors shared insights and validated this list of barriers.

Dialogue 6

OPPOSITE PAGE

Top left: *Dr. S. Julio Friedmann, Principal Deputy Assistant Secretary for Fossil Energy, U.S. Department of Energy; Dr. Edward Ray, President, Oregon State University; and Chad Evans, Executive Vice President, Council on Competitiveness.*

Top right: *Presentation at the Food Innovation Center, a joint initiative between Oregon State University and the Oregon Department of Agriculture.*

Bottom left: *Roundtable Discussion at AEMC Advanced Materials Dialogue 6 in Portland, Oregon.*

Bottom right: *Chad Evans, Executive Vice President, Council on Competitiveness; Dr. Edward Ray, President, Oregon State University; Dr. S. Julio Friedmann, Principal Deputy Assistant Secretary for Fossil Energy, U.S. Department of Energy; Dr. Cynthia Powell, Director, Office of Research & Development, National Energy Technology Laboratory; Dr. Mark Johnson, Director, Advanced Manufacturing Office, Office of Energy Efficiency & Renewable Energy, U.S. Department of Energy; Dr. Andrew Steigerwald, Senior Policy Director, Council on Competitiveness; Dr. Bhima Sastri, Program Manager, Advanced Combustion & Fuel Cells, Office of Fossil Energy, U.S. Department of Energy; and Reuben Sarker, Deputy Assistant Secretary for Transportation, Office of Energy Efficiency & Renewable Energy, U.S. Department of Energy.*

Dialogue 7

THIS PAGE

Top left: *Dr. Mark Johnson, Director, Advanced Manufacturing Office, Office of Energy Efficiency & Renewable Energy, U.S. Department of Energy.*

Top right: *Dr. Leo Christodoulou, Director, Structures and Materials, Enterprise Operations and Technology, The Boeing Company; Chad Evans, Executive Vice President, Council on Competitiveness; and Dr. Peter Littlewood, Director, Argonne National Laboratory.*

Bottom left: *Roundtable Discussion at AEMC Advanced Materials Dialogue 7 at Argonne National Laboratory.*

Bottom right: *Presentation at the Advanced Photon Source at Argonne National Laboratory.*

- **Capital Requirements:** While insufficient capital is often attributed to a dearth of new innovative energy technologies, insufficient capital also strangles the design, development, manufacture and deployment of advanced materials. The amount of investment required to design, develop, manufacture, and deploy advanced materials can shelf a project mid-stream or even inhibit a project from beginning.
- **Overcoming Technical Uncertainty & Imperfect Information:** Market incentives encourage firms to focus on low-risk, incremental improvements to existing technologies rather than investing in new and unproven transformational technologies. Often, innovators and investors lack adequate information to make informed decisions. These high technical risks dampen the incentives to the increased creation and use of new technologies.

Dialogue 8

Top left: *The Honorable Deborah L. Wince-Smith, President & CEO, Council on Competitiveness; Dr. M. Katherine Banks, Vice Chancellor and Dean of Engineering, Director, Texas A&M Engineering Experiment Station, Texas A&M University; and Regis Conrad, Director, Division of Advanced Energy Systems, U.S. Department of Energy.*

Top right: *AEMC Advanced Materials Dialogue 8 at Texas A&M, outside the Annenberg Presidential Conference Center at the George Bush Library.*

At left: *Dr. Mark Johnson, Director, Advanced Manufacturing Office, Office of Energy Efficiency & Renewable Energy, U.S. Department of Energy.*

- **Industrial Innovation Infrastructure & Expertise:** This barrier refers to a lack of access to shared infrastructure and expertise on which industry scientists and engineers could draw to increase speed and lower costs on the path from design to production and commercialization. Typically, innovation infrastructure refers not only to shared research and testing equipment, but also to university or national laboratory personnel with specialized knowledge and skills.

To align efforts in both the public and private sectors, a national initiative to support advanced materials could be built around (1) specific classes of advanced materials, (2) specific processes for a wide variety of advanced materials, or (3) specific tools or activities useful for a wide variety of advanced materials. A selection of advanced materials and specific tools or activities is discussed in greater detail in the following section.

A national advanced materials initiative could:

1. Support the design, development, manufacture and deployment of classes of advanced materials, such as:
   a. Alloys
   b. Separation products
   c. Coatings
   d. Catalysts
2. Support the research, development and demonstration for all materials of processes, such as:
   a. Modeling/design
   b. Synthesis
   c. Processing/manufacturing
   d. Characterization
   e. Application
3. Support the development of and access to tools or activities for all materials, such as:
   a. Public sector capabilities map
   b. Materials data repository, management and informatics
   c. Increased access to tools
   d. High-throughput simulations and experimentation

Potential Classes of Advanced Materials

After gathering input from stakeholders, the Council and the Department of Energy have considered the acceleration of advanced materials into products and processes in the marketplace as a cross-cutting method to achieve the goals of the Clean Energy Manufacturing Initiative. By engaging a broad industrial community and increasing access to national innovation capabilities—including expertise and tools—advanced materials may be better designed, developed, manufactured, and deployed to both accelerate the development and commercialization of clean energy technologies and increase the energy productivity of many sectors of the economy.

Several materials classes have a great potential to cross-cut many types of technologies and sectors of the economy—in addition to improving the productivity and competitiveness of the sectors—with relevance and interest across the Department of Energy Office of Fossil Energy, Office of Energy Efficiency and Renewable Energy, and Office of Nuclear Energy, including next generation alloys, separation materials such as sorbents and membranes, catalysts and coatings.[3]

Alloys

The desire for superior characteristics in metals has driven research in a continuous quest to find alloys that are stronger, more ductile, formable, corrosion resistant, high melting temperatures, yet capable of being joined, coated, and manufactured at low cost.

Inconel is an example of an alloy under investigation with funding from the Department of Energy for use in advanced ultra-supercritical steam boilers

Figure 1: Extrusion of Inconel 740H Pipe at Wyman Gordon plant
Source: Shingledecker, J. et al. 2013

(at temperatures up to 760 degrees Celsius and pressures up to 5500 pounds per square inch) which will allow for the generation of electricity from coal-fired power plants at higher efficiency.[4] Materials such as Inconel have additional applicability for high temperature, high pressure piping in gas fired carbon dioxide Brayton cycles for carbon capture and solar powered carbon dioxide Brayton cycles.[5] By better understanding microstructural factors, steam-side oxidation resistance, and other characteristics that can help predict the life of alloys, a national initiative supporting further work in alloys could help accelerate the design, development, char-

3 This initiative will also collaborate with and integrate efforts from The Materials Project (www.materialsproject.org) and the National Network of Manufacturing Innovation Institutes.

4 Viswanathan, R. et. al. U.S. Program on Materials Technology for USC Power Plants. Advances in Materials Technology for Fossil Power Plants. 2005 ASM International.

5 Shingledecker, J. et al. Materials Technology to Enable High-Efficiency Advanced Ultrasupercritical (A-USC) Steam Power Plants. "Advanced Technologies & Best Practices for Supercritical Thermal Power Plants." Partnership to Advance Clean Energy-Deployment (PACE-D) Technical Assistance Program (U.S. AID), 2013.

Figure 2: PEEK Hollow fiber membrane contactor developed to increase the efficiency of carbon capture from power plant flue gas
Source: Li, S. et al. 2014

Figure 3: Aluminum fins from a geothermal power plant subjected to 24,000 cycles of exposure to briny conditions with: no protective coating (left), nano-coating with a low level of Cerium Oxide (middle), and a nano coating with a higher concentration of Cerium Oxide (right).
Source: Larsen, KR, 2009

acterization and standardization of alloys like Inconel and stimulate faster and greater deployment into the marketplace.

Separation Products

Advanced materials that can increase the efficiency of separations processes could have an outsized impact on the energy and manufacturing sectors. Sorbents and membranes are two types of products used in applications such as carbon sequestration, fuel cells, chemical processing, and removing impurities from fluids ranging from power plant flue gas and water filtration.

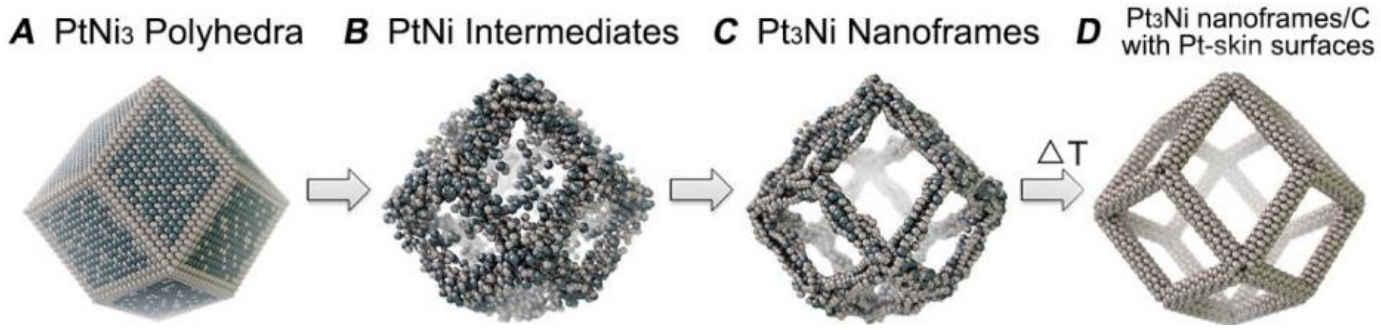
Membranes like the poly (ether ether ketone) (PEEK) hollow fiber membrane can be used to separate carbon dioxide (CO_2) from flue gas, which is then absorbed into a liquid.[6] By supporting further study and development of separation products or increasing access to tools such as high-throughput simulations and experimentation, a national initiative could unleash the potential of advanced materials for separation processes—verifying products that can separate desired components at preferred conditions such as higher pressures and temperatures and low concentrations, with reduced degradation over time.

Coatings

Coatings can increase the durability and corrosion resistance of metals and other materials, increasing the lifetime of products and reducing downtime of processes across the energy and manufacturing sectors. Advanced materials for coatings are especially important for extreme environments, where resistance to degradation by high temperatures and

6 Li, S. et al. "Post-combustion CO_2 Capture Using PEEK Hollow Fiber Membrane Contactors." 2014.

Figure 4: Illustrations showing the evolution of platinum/nickel catalyst from a solid polyhedral structure to nanoframes with platinum-enriched skin.
Source: Lawrence Berkeley National Laboratory, 2014.



corrosive chemicals must be explored in addition to other desirable coating qualities such as good adherence while remaining inert with many substrates including varying types of metals and alloys, and low toxicity.

Coatings like an ultrathin coating with rare-earth metal oxide nanoparticles mitigate the corrosion effects from brine in aluminum fins in air-cooled condensers at geothermal power plants.[7] By increasing access to materials data and expertise, modeling and simulation capabilities, and high throughput experimentation tools, a national initiative could continue the discovery of durable, economical, and more environmentally friendly coatings in addition to efficient and optimal methods for their application to substrates.

Catalysts

Catalysts are commonly used in technologies and processes to increase the rate of desired chemical reactions and inhibit undesired reactions across sectors including chemical and petrochemical industries, the pharmaceutical industry, and power production for electricity and vehicles. Research continues to race forward in catalysis to find methods to create more effective and less expensive catalysts, find methods to increase exposure to catalysts, and reduce the degradation of catalysts from poisons and long periods of exposure to potentially harsh environments.

Catalysts like the nanoframe platinum nickel catalyst generated for fuel cells, have been designed and produced to use roughly 85 percent less platinum while enjoying over 30 times the catalytic activity of platinum dispersed on carbon.[8] Further developments in catalysis could benefit from increased access to tools and expertise in a national initiative, moving forward new discoveries such as these platinum nickel nanoframes into manufacturable and deployable products more quickly and with less expense.

7 Larsen, KR. "Corrosion-resistant coatings incorporate metal oxide nanoparticles." Materials Performance, 2009.

8 "Big Step for Next-Generation Fuel Cells and Electrolyzers." Lawrence Berkeley National Laboratory, 2014.

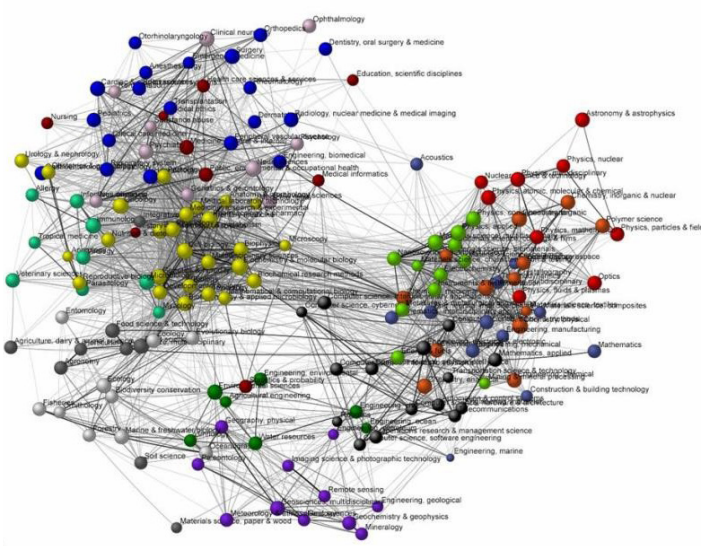
Potential Activities in a National Advanced Materials Initiative

Another potential way for the Department of Energy to create a national initiative to accelerate the design, development, manufacture, and deployment of advanced materials is to support specific activities that apply to a wide variety of material classes. These activities could include resources within our unparalleled U.S. national laboratory complex and the university research system. Within the wide-array of expertise, capabilities and scientific user facilities housed at these global centers of innovation and excellence, the Department of Energy is working to leverage advanced manufacturing expertise and infrastructure in addition to developing tools with the potential to accelerate advanced materials manufacturing from materials discovery through deployment. A national initiative could be designed to include some of the following activities:

Mapping Public Sector Capabilities

The Department of Energy Technology Transfer program provides a mechanism to search for expertise and facilities in specific scientific and technological areas of interest through the DOE national laboratories.[9] The Department of Energy, could fund and expand this effort into a full map of public sector capabilities through a national initiative, potentially even paired with a matchmaking or concierge service that could help private sector organizations find the relevant tools and expertise within the national laboratory and university research ecosystems.

Figure 5: Institute for Scientific Information (ISI) subject categories connected by correlating citations
Source: Leydesdorff.net



Create a materials data repository

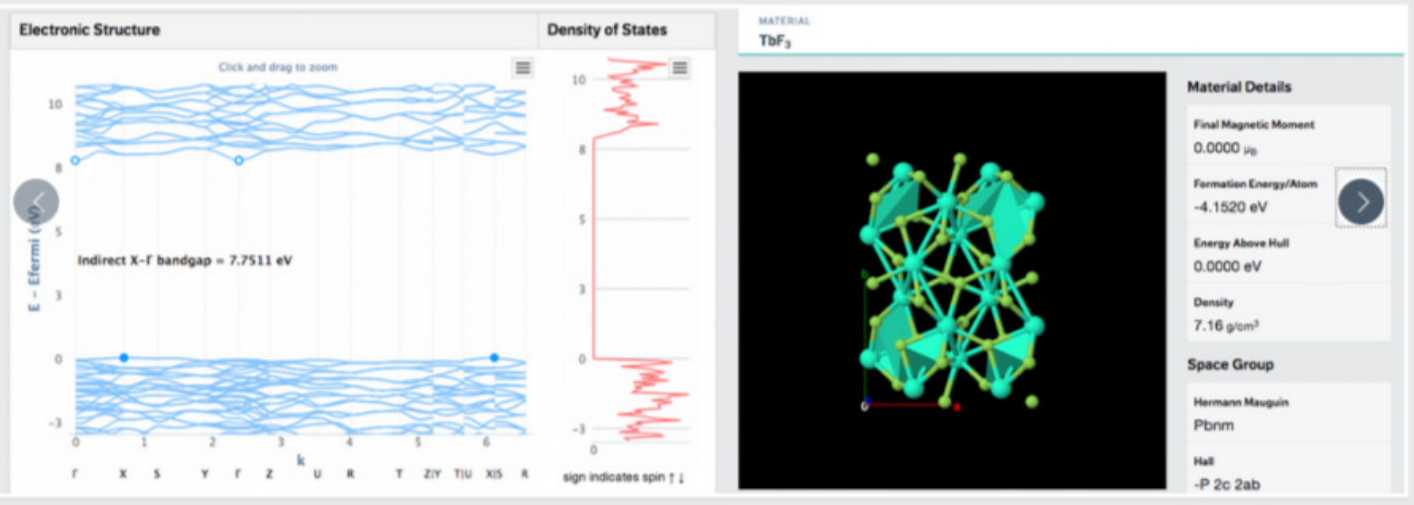
The Materials Project,[10] a core program in the Materials Genome Initiative, harnesses the power of supercomputing and data to provide open web-based access to computed information on known and predicted materials as well as powerful analysis tools to inspire and design novel materials.

There is a great potential to unleash a surge in American prosperity and productivity by continuing and expanding the Materials Project as part of a national initiative. Integrating knowledge from many types of materials research across the research and development ecosystem into one central repository could create a searchable system could reduce

9 Department of Energy, http://techtransfer.energy.gov/doelabwork.

10 The Materials Project, https://www.materialsproject.org/.

Figure 6: Information available on Terbium Fluoride (TbF3) from the Materials Project
Source: www.materialsproject.org



redundancies in research and shorten the time to discover appropriate materials for a given purpose. In addition, being able to also access computer software and hardware tools and expertise to complete computations using readily available and intelligible data could benefit both university and national laboratory based research in addition to research for private sector companies.

Increase Access to Tools

The Department of Energy's national laboratory complex and supported university research programs are fountains of expertise, capabilities, and scientific user facilities that can be applied to accelerating the design, development, manufacture, and deployment of advanced materials. These resources have a history of partnering with industry to overcome industry problems, and while many good examples of success exist,[11,12,13] the broader community has not yet benefited.

Through a national initiative to accelerate the design, development, manufacture, and deployment of advanced materials, the Department of Energy could clarify the methods to approach and use these capabilities at the national laboratories and university

11 Council on Competitiveness. Case Study: Goodyear Puts the Rubber to the Road with High Performance Computing. 2009. More information available at: http://www.compete.org/publications/detail/685/good-year-puts-the-rubber-to-the-road-with-high-performance-computing/.

12 Albuquerque Business First. "Los Alamos honors team for work with P&G." August 2013. Available at: http://www.bizjournals.com/albuquerque/blog/morning-edition/2013/08/los-alamos-honors-team-for-work.html.

13 Los Alamos National Laboratory. Chevron, GE form Technology Alliance. February 2014. Available at: http://www.lanl.gov/newsroom/news-releases/2014/February/02.03-chevron-ge-tech-alliance.php.

Figure 7: The Advanced Photon Source at Argonne National Laboratory
Source: Argonne National Laboratory

research programs, or fund projects for individual companies to use these capabilities towards solving industry-relevant problems.

High-throughput Simulations and Experimentation

A national initiative could help develop and demonstrate coupled high-throughput simulations and experimentation techniques for advanced materials—parallelizing simulations and experiments to examine a large space of interest over a short period of time. By integrating these methods and making the infrastructure available, the initiative could provide a different approach to materials research that could, more quickly and with less expense, help discover relevant and novel materials for existing industrial needs.

Figure 8: The new "Catalyst" supercomputer available at Lawrence Livermore National Laboratory for collaborative projects with American industry pairs Big Data with high performance computing power.
Source: High Performance Computing Innovation Center at the Livermore Valley Open Campus

Figure 9: Using the power high-throughput experimentation to simultaneously synthesize or test hundreds of materials.
Source: SYMYX PHOTO, American Chemical Society 2001.

Looking Forward

AEMC Partnership *Materials Manufacturing Accelerator* Dialogues 6-8 present potential ways to focus in on ways to bring advanced materials into manufactured processes and products and deploying these materials into the marketplace. Suggesting focus on specific classes of materials, specific capabilities for all advanced materials, or specific tools and activities that can be applied to large swaths of material classes—or a mixture of the three—the Council and the Department of Energy look forward to hearing the perspectives of decision makers on the best methods to accelerate the use of advanced materials. Dialogue participants are asked to consider the following key questions:

1. What barriers hinder development and deployment of advanced materials in your company? In your sector?
2. How can the public and private sectors work together to create a national initiative to integrate advanced materials into manufactured processes and products better, faster, cheaper?
3. How can the *Materials Manufacturing Accelerator* initiative encourage participation across the private sector—across industries, companies of all sizes, and technological expertise?

The Department of Energy will consider feedback from this dialogue series as it moves forward in the creation of a Materials Manufacturing Accelerator initiative with organizations across the innovation ecosystem.

2015 Accelerating Advanced Materials Manufacturing Dialogues

Dialogue 6
May 8, 2015

HOSTS

Dr. Edward Ray
President
Oregon State University and

Dr. Cynthia Powell
Director, Office of Research and Development
National Energy Technology Laboratory

LOCATION

Food Innovation Center
Oregon State University
1207 NW Naito Pkwy #154
Portland, OR 97209

MORNING

8:00 Registration and Light Breakfast

8:30 Welcome and Opening Remarks

Mr. Chad Evans
Executive Vice President
Council on Competitiveness

Dr. Edward Ray
President
Oregon State University

Dr. S. Julio Friedmann
Principal Deputy Assistant Secretary
Clean Coal and Carbon Management
U.S. Department of Energy

Dr. Cynthia Powell
Director
Office of Research & Development
National Energy Technology Laboratory

9:00 Briefing on the Goals and Objectives of the Clean Energy Manufacturing Initiative (CEMI)

This session will describe the thrusts and new developments in the Department of Energy (DOE) Clean Energy Manufacturing Initiative (CEMI), created in the Office of Energy Efficiency and Renewable Energy (EERE) and joined by the Offices of Fossil Energy (FE) and Nuclear Energy (NE). This overview will highlight the critical role of advanced materials—and in particular, a national initiative around accelerating the manufacturing of such materials—plays in achieving the overarching goals of CEMI.

Mr. Reuben Sarkar
Deputy Assistant Secretary for Transportation
Office of Energy Efficiency & Renewable Energy
U.S. Department of Energy

9:15 Extreme Environment Materials

DOE has a vested interest in facilitating the design, development, and deployment of advanced materials—in particular those that exist and operate in extreme environments or under harsh conditions. These materials enable technologies that cross-cut DOE—applications such as A-USC and supercritical CO_2 power cycles, advanced nuclear cycles, advanced turbines, safe and reliable drilling, geothermal cycles, industrial waste heat recovery, and concentrated solar power cycles. This session will give an overview of the work at NETL in these areas and lay a foundation for the following sessions focused on accelerating these material systems into the marketplace.

Dr. Cynthia Powell
Director
Office of Research & Development
National Energy Technology Laboratory

9:30 Identifying Common Challenges

Moderator

Mr. Chad Evans
Executive Vice President
Council on Competitiveness

Advanced materials includes a wide range of materials, applications and processes—from nanoscale films and coatings, to advanced alloys and composites, to innovative recycling processes. In spite of this diversity, a number of common challenges exist that—if addressed—could accelerate the development and deployment of a wide range of materials and technologies into the marketplace.

In this opening session, participants will introduce themselves and discuss what—from their perspective—are the most significant challenges to furthering the manufacturing of advanced materials in the U.S.

Questions to consider
- What does the term "advanced materials" mean to you and your organization?
- How do you see your role in the research, development and deployment of advanced materials and materials-based technologies?
- What challenges do you perceive as being barriers to the manufacturing scale-up and deployment of advanced materials and what are potential solutions?

10:45 Coffee Break

11:00 Aligning Resources and Capabilities with Needs

Moderator

Dr. Cynthia Powell
Director, Office of Research and Development
National Energy Technology Laboratory

Three barriers have been highlighted as important to unleashing the potential for deployment of advanced materials faster in the United States: insufficient access to capital, insufficient access to shared infrastructure, and high technical risks. In this discussion, participants will suggest tools and capabilities to include in a national initiative that could help overcome these barriers, in addition to other shared barriers identified in the first session.

Questions to consider
- What potential "platform" or "horizontal" technologies, systems or processes are most beneficial to the advanced materials space?
- In developing and deploying advanced materials, where is access to capital most critical? Where is it most constrained? What innovative financing mechanisms could be applied to accelerate advanced materials into the marketplace?
- What types of shared infrastructure are most useful and effective? To what degree can the right shared infrastructure derisk potential investments in new advanced materials?

Kickoff Discussants

Mr. Chris Colbert
Chief Strategy Officer
NuScale

Mr. Matthew Carter
Associate Technical Fellow
The Boeing Company

Mr. Robert "Skip" Rung
President & Executive Director
Oregon Nanoscience and Microtechnologies Institute (ONAMI)

AFTERNOON

12:15 Lunch and Lab Tour

The Food Innovation Center is a joint initiative between Oregon State University (OSU) and the Oregon Department of Agriculture (ODA) to foster the success of food and agricultural enterprises by supporting food innovation throughout all industry sectors. The FIC is located in the Pearl District of Portland, OR.

1:30 The Role of Modeling: Developing a Virtual Materials Design and Testing Platform

Moderator

Dr. Ron Adams
Interim Director, Vice President for Research
Oregon State University

Many researchers and companies are accustomed to designing, developing, and deploying materials based on experiments and experience. Incorporating virtual design and testing into this process has the potential to increase competitiveness and energy productivity. Dialogue participants will discuss the major challenges in implementing virtual design and testing and steps needed to overcome these challenges.

Questions to consider
- What is the potential virtual materials design to spur innovation and solve challenges you face in the design and development of new materials and technologies?
- What are the barriers to wider adoption and use of virtual materials design and testing?
- What strategic investments could leverage existing resources and capabilities in virtual materials design that would create real and extensive impact?

Kickoff Discussants

Mr. Greg Mulholland
Co-Founder and Chief Operating Officer
Citrine Informatics

Dr. Suresh Baskaran
Chief Science and Technology Officer, Energy and Environment Directorate
Pacific Northwest National Laboratory

3:00 Coffee Break

3:15 Accelerating Advanced Materials Manufacturing Next Steps

Moderator

Dr. S. Julio Friedmann
Principal Deputy Assistant Secretary for Fossil Energy
U.S. Department of Energy

Dialogue participants will discuss different structures for a public-private partnership (or program) that create clear and concise guidelines as well as potential funding mechanisms for this potential national initiative (managed by consortia, user-facility, NNMI, privately funded incubator, etc.).

Discussants will share their perspectives on the necessary markers along a roadmap to creating an initiative around accelerating advanced materials manufacturing.

Questions to consider

- What are immediately actionable first steps that can pave the way towards designing, developing and deploying advanced materials?
- What are necessary steps in the roadmap for the next 2-5 years that ensure effectiveness, accessibility, and differentiation from existing public-private partnerships?
- What are the critical features in public-private partnerships that lead to success?
- How can a national initiative based on advanced materials encourage participation across the private sector—across industries, companies of all sizes, and technological expertise?

Kickoff Discussants

Dr. Kristen Bloschock
Advanced Materials Lead, Advanced Manufacturing
Lockheed Martin Corporation

Mr. Jeff Dyck
Senior Vice President and President, Steel Manufacturing Business
Schnitzer Steel Industries, Inc.

Mr. David Kenney
President & Executive Director
Oregon Built Environmentally Sustainable Technologies

4:15 The Path Forward

Dr. Edward Ray
President
Oregon State University

Dr. Cynthia Powell
Director, Office of Research and Development
National Energy Technology Laboratory

Dr. S. Julio Friedmann
Principal Deputy Assistant Secretary
Office of Fossil Energy
U.S. Department of Energy

Mr. Chad Evans
Executive Vice President
Council on Competitiveness

4:30 Conclude and Reception

PARTICIPANTS

Dr. Ron Adams
Interim Vice President for Research
Oregon State University

Dr. David Alman
Director, Structural Materials
Development Divison
National Energy Technology Laboratory

Mr. Brad Atchison
Project Manager
MLD Technologies

Dr. Suresh Baskaran
Chief Science and Technology Officer
Energy and Environment Directorate
Pacific Northwest National Laboratory

Dr. Kristen Bloschock
Advanced Materials Lead, Advanced Manufacturing
Lockheed Martin Corporation

Dr. Mark Carroll
Staff Scientist
Idaho National Laboratory

Mr. Matthew Carter
Associate Technical Fellow
The Boeing Company

Mr. Chris Colbert
Chief Strategy Officer
NuScale

Dr. Regis Conrad
Director, Division of Crosscutting Research
U.S. Department of Energy

Mr. Jeff Dyck
Senior Vice President and President, Steel Manufacturing Business
Schnitzer Steel Industries, Inc.

Mr. Chad Evans
Executive Vice President
Council on Competitiveness

Dr. S. Julio Friedmann
Principal Deputy Assistant Secretary for Fossil Energy
U.S. Department of Energy

Mr. David Goin
Business Development Project Manager
Allegheny Technologies (ATI)

Mr. Brad Hanna
Metallurgist
Portland Gas and Electric

Dr. Mark Hartney
Director, Office of Strategic Planning
SLAC National Accelerator Laboratory

Dr. Mark Johnson
Director, Advanced Manufacturing Office
U.S. Department of Energy

Dr. Patrick Jones
Associate Vice President for Research and Innovation
University of Oregon

Mr. David Kenney
President & Executive Director
Oregon Built Environmentally Sustainable Technologies

Dr. Paul King
President & Executive Director
KW Associates

Mr. Mark Lamey
Director—Manufacturing Development Group
Blount International

Mr. Greg Mulholland
Co-Founder and Chief Operating Officer
Citrine Informatics

Dr. Daniel Mumm
Associate Professor, Chemical Engineering and Materials Science
University of California, Irvine

Dr. Shailesh Patel
Vice President, Research and Technology
Special Metals Corp.

Dr. Cynthia Powell
Director
Office of Research and Development
National Energy Technology Laboratory

Dr. Edward Ray
President
Oregon State University

Mr. Robert “Skip” Rung
President & Executive Director
Oregon Nanoscience and Microtechnologies Institute (ONAMI)

Mr. Reuben Sarkar
Deputy Assistant Secretary for Transportation, Office of Energy, Efficiency & Renewable Energy
U.S. Department of Energy

Dr. Bhima Sastri
Program Manager, Advanced Combustion & Fuel Cells
U.S. Department of Energy

Mr. Don Stevenson
Senior Director—Energy Systems
Aerojet Rocketdyne

Mr. Parry Walborn
Vice President and Director, ATI Nuclear Energy Market Sector Team
Allegheny Technologies Inc.

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

STAFF

Dr. Drew Steigerwald
Senior Policy Director
Council on Competitiveness

Dr. Ann Schmierer
Director of Industry Partnering
Oregon State University

Dr. David Cann
Associate Head for Graduate Programs,
Department of Mechanical, Industrial and
Manufacturing Engineering
Oregon State University

Dr. Jack deBarbadillo
Director Product and Process
Development
Special Metals Corp.

Dr. Vince Remcho
Patricia Valian Reser Faculty Scholar,
Department of Chemistry
Oregon State University

Ms. Cathy Summers
Office of Research & Development -
Education, Collaboration, and Outreach
Programs
National Energy Technology Laboratory

Mr. Eli Levine
Deputy Director, Clean Energy
Manufacturing Institute
U.S. Department of Energy

Dialogue 7
June 25, 2015

HOSTS

Dr. Peter Littlewood
Director
Argonne National Laboratory

Mr. David Mohler
Deputy Assistant Secretary, Clean Coal and Carbon Management
Office of Fossil Energy
U.S. Department of Energy

LOCATION

Advanced Photon Source
Building 401, Rm. A5000
Argonne National Laboratory
Lemont, IL

MORNING

8:00 Registration and Light Breakfast

8:30 Welcome and Opening Remarks

Mr. Chad Evans
Executive Vice President
Council on Competitiveness

Dr. Peter Littlewood
Director
Argonne National Laboratory

Mr. David Mohler
Deputy Assistant Secretary, Clean Coal and Carbon Management
Office of Fossil Energy
U.S. Department of Energy

9:00 Briefing on the Goals and Objectives of the Clean Energy Manufacturing Initiative (CEMI)

This session will describe the thrusts and new developments in the Department of Energy (DOE) Clean Energy Manufacturing Initiative (CEMI), created in the Office of Energy Efficiency and Renewable Energy (EERE) and joined by the Offices of Fossil Energy (FE) and Nuclear Energy (NE). This overview will highlight the critical role of advanced materials—and in particular, a national initiative around accelerating the manufacturing of such materials—plays in achieving the overarching goals of CEMI.

Mr. Reuben Sarkar
Deputy Assistant Secretary for Transportation
Office of Energy Efficiency & Renewable Energy
Executive Director, CEMI
U.S. Department of Energy

9:15 Understanding Materials in Extreme Environments at Argonne National Lab

DOE has a vested interest in understanding the design, development, and deployment of advanced materials—in particular those that exist and operate in extreme environments or under harsh conditions. These materials enable technologies that cross-cut DOE—applications such as novel catalysts for advanced fuel cell technology, extreme tolerance to photon and particle fluxes, advanced reactor and fuel cycle technologies, energy storage for the electric transportation grid, and others. This session will give an overview of how DOE's unique user facilities, like Argonne's Advanced Photon Source and the Center for Nanoscale Materials, are working in concert to accelerate discovery and bring these technologies into the marketplace.

Dr. Stephen Streiffer
Associate Laboratory Director, Photon Sciences
Argonne National Laboratory

9:30 Identifying Common Challenges

Moderator

Dr. Mark Johnson
Director, Advanced Manufacturing Office
Office of Energy Efficiency & Renewable Energy
U.S. Department of Energy

Advanced materials includes a wide range of materials, applications and processes—from nanoscale films and coatings, to advanced alloys and composites, to innovative recycling processes. In spite of this diversity, a number of common challenges exist that—if addressed—could accelerate the development and deployment of a wide range of materials and technologies into the marketplace.

In this opening session, participants will introduce themselves and discuss what—from their perspective—are the most significant challenges to furthering the manufacturing of advanced materials in the U.S.

Questions to consider
- What does the term "advanced materials" mean to you and your organization?
- How do you see your role in the research, development and deployment of advanced materials and materials-based technologies?
- What challenges do you perceive as being barriers to the manufacturing scale-up and deployment of advanced materials and what are potential solutions?

10:30 Coffee Break

10:4 Aligning Resources and Capabilities with Needs

Moderator

Dr. Matthew Tirrell
Dean and Founding Pritzker Director
The Institute for Molecular Engineering
University of Chicago

Three barriers have been identified as impediments to the scale-up and deployment of new materials—access to capital at critical points in technology development, access to shared infrastructure, and high technical risk. These issues are particularly relevant to extreme environment materials, where non-equilibrium conditions can lead to greater uncertainties and new behaviors. In this session participants will develop specific recommendations that could—if implemented—facilitate quicker development and market diffusion of new materials.

Questions to consider
- As new materials are developed, where is access to capital most constrained? What would facilitate more private sector investment at these critical points? What other financing mechanisms should be considered?
- What would shared infrastructure capable of benefiting a broad class of materials look like? What is needed to be able to address challenges specifically related to the manufacturing of new materials?
- What other approaches—beyond financing tools—can help to derisk investments in the scale-up of new materials?

Kickoff Discussants

Mr. Adam Khan
Founder and CEO
AKHAN Semiconductor

Dr. Roger England
Director, Materials Science & Technology, Intellectual Property, and Technical Quality
Cummins, Inc.

Mr. Mike Froehlich
Global Technology Manager, Advanced Mechanical Technologies
Eaton Corporation

AFTERNOON

12:00 Working Lunch (and Tour)

1:30 Shortening the RD&D Cycle: The Role of Predictive Modeling

Moderator

Dr. Peter Littlewood
Director
Argonne National Laboratory

Many researchers and companies are accustomed to designing, developing, and deploying materials based on experiments and experience. Incorporating virtual materials design (VMD) and testing into this process has the potential to accelerate this cycle by informing the search for new classes of materials with specific behaviors that will perform un der extreme conditions. In this session participants will share their perspective on the potential of predictive modeling and what can be done to spur its wider adoption.

Questions to consider
- How do you view the potential of VMD in your own line of work? What barriers (awareness, access, usefulness) have you observed in its application?
- What can be done to spur wider adoption and use of VMD in the testing and design cycle? What is DOE's role in this?
- What existing resources could be leveraged to drive greater use of VMD in the private sector? What specific steps need to be taken to realize this?

Kickoff Discussants

Dr. Peter Voorhees
Co-Director, Northwestern Argonne Institute for Materials Science and Engineering
Co-Director, NIST Center for Hierarchical Materials Design
Northwestern University

Dr. Glenn Fox
Associate Director, Physical and Life Sciences Directorate
Lawrence Livermore National Lab

2:15 Mitigating Risk: The Role of Materials Certification and Qualification

Confidence in the property of a novel material—how it will perform under a range of temperatures and pressures, across hundreds of thousands of cycles, in a radiative environment—is essential to its market uptake. Facilitating this process, anticipating these concerns earlier in the scale-up process, and providing this capability to small firms could dramatically accelerate the manufacturing of new classes of materials. This session will explore actionable recommendations to provide greater certification and qualification capabilities across the advanced materials sector.

Moderator

Mr. Regis Conrad
Director, Division of Crosscutting Research
U.S. Department of Energy

Kickoff Discussants

Mr. Vito Cedro
Project Manager, Crosscutting Division
National Energy Technology Laboratory

Mr. Paul Fakes
Senior Government Relations Representative
ASME

2:45 Coffee Break

3:0 Accelerating Advanced Materials Manufacturing Next Steps

Moderator

Mr. David Mohler
Deputy Assistant Secretary, Clean Coal and Carbon Management
Office of Fossil Energy
U.S. Department of Energy

Accelerating the manufacturing of new materials—and extreme environment materials in particular—requires overcoming a range of technical and non-technical barriers. Based on conversation throughout the day, this session will explore different structures for a public-private partnership (PPP) or national initiative that would drive the manufacturing of extreme environment materials in the United States.

Questions to consider

- What are the key elements of a PPP or national initiative that would address key challenges facing manufacturing of extreme environment materials?
- What gaps—financing, policy, technology or otherwise—could be immediately addressed through such an effort?
- What are the necessary next steps in developing a roadmap and milestones? What are the markers of success for a national initiative?
- How can we ensure a PPP or national initiative engages and benefits all sizes of companies and types of organizations?

Kickoff Discussants

Dr. Leo Christodoulou
Director, Structures and Materials, Enterprise Operations and Technology
The Boeing Company

Dr. Steve Visco
CEO, CTO and Founder
PolyPlus Battery

4:00 The Path Forward

Mr. David Mohler
Deputy Assistant Secretary, Clean Coal and Carbon Management
Office of Fossil Energy
U.S. Department of Energy

Mr. Chad Evans
Executive Vice President
Council on Competitiveness

4:15 Conclude and Reception

PARTICIPANTS

Mr. Vann Bush
Managing Director, Energy Supply and Conversion
Gas Technology Institute

Mr. Vito Cedro
Project Manager, Crosscutting Division
National Energy Technology Laboratory

Mr. Regis Conrad
Director, Division of Crosscutting Research
U.S. Department of Energy

Dr. Leo Christodoulou
Director, Structures and Materials, Enterprise Operations and Technology
The Boeing Company

Ms. Anne Clawson
Manager, Government Programs and Partnerships
Alcoa

Dr. Claus Daniel
Deputy Director, Sustainable Transportation Program
Oak Ridge National Laboratory

Dr. Roger England
Director, Materials Science & Technology, Intellectual Property, and Technical Quality
Cummins, Inc.

Mr. Chad Evans
Executive Vice President
Council on Competitiveness

Mr. Paul Fakes
Senior Government Relations Representative
ASME

Ms. Amy Francetic
Executive Director
Clean Energy Trust

Dr. Glenn Fox
Associate Director, Physical and Life Sciences Directorate
Lawrence Livermore National Lab

Mr. Mike Froehlich
Global Technology Manager, Advanced Mechanical Technologies
Eaton Corporation

Mr. Adam Khan
Founder and CEO
AKHAN Semiconductor

Dr. Mark Johnson
Director, Advanced Manufacturing Office
Office of Energy Efficiency & Renewable Energy
U.S. Department of Energy

Dr. Dimitris Lagoudas
Slattery Chair of Aerospace Engineering
Director, Texas Institute for Intelligent Materials and Structures
Texas A&M University

Dr. Peter Littlewood
Director
Argonne National Laboratory

Mr. David Mohler
Deputy Assistant Secretary, Clean Coal and Carbon Management
Office of Fossil Energy
U.S. Department of Energy

Mr. Greg Morin
Director, Strategy and Innovation
Argonne National Laboratory

Mr. Madhavan Narayanan
Engineering Manager, Virtual Product Development
Caterpillar Inc.

Dr. Kurt Olson
PPG Research Fellow
PPG Industries, Inc.

Dr. Bill Peter
Deputy Director, Manufacturing Demonstration Facility
Oak Ridge National Laboratory

Mr. Reuben Sarkar
Deputy Assistant Secretary for Transportation
Office of Energy Efficiency & Renewable Energy
U.S. Department of Energy

Dr. Bhima Sastri
Program Manager, Advanced Combustion & Fuel Cells
U.S. Department of Energy

Dr. Al Sattelberger
Deputy Laboratory Director
Argonne National Laboratory

Mr. Paul Seidler
Director of Commercialization
Clean Energy Trust

Dr. Stephen Streiffer
Associate Laboratory Director, Photon Sciences
Argonne National Laboratory

Dr. Dan Thoma
Director, Grainger Institute for Engineering
University of Wisconsin, Madison

Dr. Matthew Tirrell
Dean and Founding Pritzker Director
The Institute for Molecular Engineering
University of Chicago

Dr. Steve Visco
CEO, CTO and Founder
PolyPlus Battery

Dr. Peter Voorhees
Co-Director, Northwestern Argonne Institute for Materials Science and Engineering
Co-Director, NIST Center for Hierarchical Materials Design
Northwestern University

Dr. Harry Weerts
Associate Laboratory Director, Physical Sciences and Engineering
Argonne National Laboratory

Dr. David Williams
Dean of the College of Engineering
The Ohio State University

STAFF

Dr. Drew Steigerwald
Senior Policy Director
Council on Competitiveness

Mr. Eli Levine
Deputy Director, Clean Energy Manufacturing Institute
U.S. Department of Energy

Ms. Eleanor Taylor
Chief of Staff
Argonne National Laboratory

Mr. Rick Huff
Manufacturing Technology, PD&GT
Caterpillar, Inc

Dr. Suresh Sunderrajan
Director, Technology and Commercialization
Argonne National Laboratory

Dr. Mike Norman
Director, Material Sciences
Argonne National Laboratory

Dr. Emilio Bunel
Director, Chemical Sciences and Engineering
Argonne National Laboratory

Dr. Larry Curtiss
Senior Group Leader and Argonne Distinguished Fellow
Argonne National Laboratory

Mr. David Martin
Industrial Outreach, Leadership Computing
Argonne National Laboratory

Dialogue 8
August 17, 2015

HOSTS

Dr. M. Katherine Banks
Vice Chancellor and Dean of Engineering
Director, Texas A&M Engineering Experiment Station
Texas A&M University

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

Mr. Regis Conrad
Director, Division of Advanced Energy Systems
U.S. Department of Energy

LOCATION
Annenberg Presidential Conference Center at the George Bush Library
1002 George Bush Drive W.

8:00 Registration and Light Breakfast

8:30 Welcome and Opening Remarks

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

Dr. M. Katherine Banks
Vice Chancellor and Dean of Engineering
Director, Texas A&M Engineering Experiment Station
Texas A&M University

Mr. Regis Conrad
Director, Division of Advanced Energy Systems
U.S. Department of Energy

9:00 Briefing on the Goals and Objectives of the Clean Energy Manufacturing Initiative (CEMI)

This session will describe the thrusts and new developments in the Department of Energy (DOE) Clean Energy Manufacturing Initiative (CEMI), created in the Office of Energy Efficiency and Renewable Energy (EERE) and joined by the Offices of Fossil Energy (FE) and Nuclear Energy (NE). This overview will highlight the critical role of advanced materials—and in particular, a national initiative around accelerating the manufacturing of such materials—plays in achieving the overarching goals of CEMI.

Mr. Reuben Sarkar
Deputy Assistant Secretary for Transportation
Office of Energy Efficiency and Renewable Energy
Director, CEMI
U.S. Department of Energy

9:15 Understanding Materials in Extreme Environments at Texas A&M

DOE has a vested interest in understanding the design, development, and deployment of advanced materials—in particular those that exist and operate in extreme environments or under harsh conditions. These materials enable technologies that cross-cut DOE—applications such as novel catalysts for advanced fuel cell technology, extreme tolerance to photon and particle fluxes, advanced reactor and fuel cycle technologies, energy storage for the electric transportation grid, and others. This session will give an overview of how leading research institutions—like Texas A&M and others in the dialogue—are working to accelerate discovery and bring these technologies into the marketplace.

Dr. Dimitris Lagoudas
Senior Associate Dean for Research
Deputy Director, Texas A&M Engineering Experiment Station
Associate Vice Chancellor for Engineering Research
Texas A&M University

9:30 Identifying Common Challenges

Moderator

Dr. Mark Johnson
Director, Advanced Manufacturing Office
U.S. Department of Energy

Kick-Off Discussants

Dr. Ajay Malshe
CTO
Nanomech

Mr. Rustom K. Mody, P.E.
Vice President/Chief Engineer
Baker Hughes

Dr. John Stetson
Senior Fellow
Lockheed Martin

Advanced materials includes a wide range of materials, applications and processes—from nanoscale films and coatings, to advanced alloys and composites, to innovative recycling processes. In spite of this diversity, a number of common challenges exist that—if addressed—could accelerate the development and deployment of a wide range of materials and technologies into the marketplace.

In this opening session, participants will introduce themselves and discuss what—from their perspective—are the most significant challenges to furthering the manufacturing of advanced materials in the U.S.

Questions to consider

- What does the term "advanced materials" mean to you and your organization?
- How do you see your role in the research, development and deployment of advanced materials and materials-based technologies?
- What challenges do you perceive as being barriers to the manufacturing scale-up and deployment of advanced materials and what are potential solutions?

10:30 Coffee Break

10:45 Aligning Resources and Capabilities with Needs

Moderator

Mr. Chad Evans
Executive Vice President
Council on Competitiveness
Kick-Off Discussants

Dr. Costas Georghiades
Associate Dean for Research, College of Engineering
Associate Agency Director, Texas A&M Engineering Experiment Station
Texas A&M University

Dr. Ginger Rothrock
Director, Advanced Materials and System Integration
RTI International

Three barriers have been identified as impediments to the scale-up and deployment of new materials—access to capital at critical points in technology development, access to shared infrastructure, and high technical risk. These issues are particularly relevant to extreme environment materials, where non-equilibrium conditions can lead to greater uncertainties and new behaviors. In this session participants will develop specific recommendations that could—if implemented—facilitate quicker development and market diffusion of new materials.

Questions to consider

- As new materials are developed, where is access to capital most constrained? What would facilitate more private sector investment at these critical points? What other financing mechanisms should be considered?
- What would shared infrastructure capable of benefiting a broad class of materials look like? What is needed to be able to address challenges specifically related to the manufacturing of new materials?
- What other approaches—beyond financing tools—can help to derisk investments in the scale-up of new materials?

12:00 Working Lunch and Tour of the

George H.W. Bush Presidential Library

1:30 Shortening the RD&D Cycle: The Role of Predictive Modeling

Moderator

Dr. Cynthia Powell
Director, Office of Research
NETL

Kick-Off Discussant

Dr. Alan Needleman
TEES Distinguished Research Professor
Texas A&M University

Many researchers and companies are accustomed to designing, developing, and deploying materials based on experiments and experience. Incorporating virtual materials design (VMD) and testing into this process has the potential to accelerate this cycle by informing the search for new classes of materials with specific behaviors that will perform un der extreme conditions. In this session participants will share their perspective on the potential of predictive modeling and what can be done to spur its wider adoption.

Questions to consider

- How do you view the potential of VMD in your own line of work? What barriers (awareness, access, usefulness) have you observed in its application?
- What can be done to spur wider adoption and use of VMD in the testing and design cycle? What is DOE's role in this?
- What existing resources could be leveraged to drive greater use of VMD in the private sector? What specific steps need to be taken to realize this?

2:15 Mitigating Risk: The Role of Materials Certification and Qualification

Confidence in the property of a novel material—how it will perform under a range of temperatures and pressures, across hundreds of thousands of cycles, in a radiative environment—is essential to its market uptake. Facilitating this process, anticipating these concerns earlier in the scale-up process, and providing this capability to small firms could dramatically accelerate the manufacturing of new classes of materials. This session will explore actionable recommendations to provide greater certification and qualification capabilities across the advanced materials sector.

Moderator

Mr. Regis Conrad
Director, Division of Advanced Energy Systems
U.S. Department of Energy

Kick-Off Discussant

Mr. Tim Graves
Director of Operations, Technical Events and Content Sector
ASME

2:45 Coffee Break

3:0 Accelerating Advanced Materials Manufacturing Next Steps

Moderator

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

Kick-Off Discussants

Dr. Scott Fish
Senior Research Scientist
Executive Director of the Advanced Manufacturing Center
University of Texas in Austin

Mr. James Phillips
Chairman and CEO
Nanomech

Accelerating the manufacturing of new materials—and extreme environment materials in particular—requires overcoming a range of technical and non-technical barriers. Based on conversation throughout the day, this session will explore different structures for a public-private partnership (PPP) or national initiative that would drive the manufacturing of extreme environment materials in the United States.

Questions to consider

- What are the key elements of a PPP or national initiative that would address key challenges facing manufacturing of extreme environment materials?
- What gaps—financing, policy, technology or otherwise—could be immediately addressed through such an effort?
- What are the necessary next steps in developing a roadmap and milestones? What are the markers of success for a national initiative?
- How can we ensure a PPP or national initiative engages and benefits all sizes of companies and types of organizations?

4:00 The Path Forward

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

Dr. M. Katherine Banks
Vice Chancellor and Dean of Engineering
Director, Texas A&M Engineering Experiment Station
Texas A&M University

Mr. Regis Conrad
Director, Division of Advanced Energy Systems
U.S. Department of Energy

4:15 Conclusion and Reception

PARTICIPANTS

Dr. M. Katherine Banks
Vice Chancellor and Dean of Engineering
Director, Texas A&M Engineering Experiment Station
Texas A&M University

Dr. Barron Bichon
Manager of Probabilistic Mechanics
Southwest Research Institute

Dr. Satish T.S. Bukkapatnam
Professor
Rockwell International Professor
Director, TEES Institute for Manufacturing Systems
Texas A&M University

Mr. Vito Cedro
Project Manager, Crosscutting Division
National Energy Technology Laboratory

Mr. Regis Conrad
Director, Division of Advanced Energy Systems
U.S. Department of Energy

Dr. Marie-Nathalie Contou-Carrere
Corporate Research Development
Energy and Environment Initiative
Rice University

Mr. Chad Evans
Executive Vice President
Council on Competitiveness

Dr. Scott Fish
Senior Research Scientist
Executive Director of the Advanced Manufacturing Center
University of Texas in Austin

Dr. Costas Georghiades
Associate Dean for Research, College of Engineering
Associate Agency Director, Texas A&M Engineering Experiment Station
Texas A&M University

Mr. Tim Graves
Director of Operations, Technical Events and Content Sector
ASME

Dr. Mark Johnson
Director, Advanced Manufacturing Office
U.S. Department of Energy

Dr. Dimitris Lagoudas
Senior Associate Dean for Research
Deputy Director, Texas A&M Engineering Experiment Station
Associate Vice Chancellor for Engineering Research
Texas A&M University

Mr. Eli Levine
Deputy Director, CEMI
U.S. Department of Energy

Dr. Jun Lou
Associate Professor of Materials Science and Nano Engineering
Rice University

Dr. Ajay Malshe
CTO
Nanomech

Sean M. McDeavitt
Associate Professor
Interim Nuclear Science Center (NSC) Director
Texas A&M University

Mr. Rustom K. Mody, P.E.
Vice President/Chief Engineer
Baker Hughes

Dr. Jon Mogford
Vice Chancellor for Research
The Texas A&M University System

Dr. Alan Needleman
TEES Distinguished Research Professor
Texas A&M University

Dr. Kevin Nowka
Director
IBM Research—Austin

Dr. Matteo Pasquali
Professor of Chemical and Biomolecular Engineering and Chemistry
Rice University

Dr. David Pattillo
Tubular Design Advisor
Anadarko Petroleum Corporation

Mr. James Phillips
Chairman and CEO
Nanomech

Dr. Cynthia Powell
Director, Office of Research
NETL

Dr. Ginger Rothrock
Director, Advanced Materials and System Integration
RTI International

Mr. Reuben Sarkar
Deputy Assistant Secretary for Transportation
Office of Energy Efficiency and Renewable Energy
Director, CEMI
U.S. Department of Energy

Dr. Bhima Sastri
Program Manager, Advanced Combustion & Fuel Cells
U.S. Department of Energy

Dr. John Stetson
Senior Fellow
Lockheed Martin

Mr. Steve Stich
Director of Exploration Integration
Johnson Space Center

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

About the Council on Competitiveness

Who We Are

Founded in 1986, the Council on Competitiveness is a non-partisan leadership organization of corporate CEOs, university presidents, labor leaders and national laboratory directors committed to advancing U.S. competitiveness in the global economy and a rising standard of living for all Americans.

Dedicated to building U.S. prosperity, the Council plays a powerful role in shaping America's future by setting an action agenda to assess U.S. competitiveness, identify emerging forces transforming the economy, catalyze thought leaders who drive change and galvanize stakeholders to act.

Council on Competitiveness
900 17th Street, NW, Suite 700
Washington, D.C. 20006, USA
T 202 682 4292
F 202 682 5150
www.compete.org

How We Operate

The key to U.S. prosperity in a global economy is to develop the most innovative workforce, educational system and businesses that will maintain the United States' position as the global economic leader.

The Council achieves its mission by:

- Identifying and understanding emerging challenges to competitiveness
- Generating new policy ideas and concepts to shape the competitiveness debate
- Forging public and private partnerships to drive consensus
- Galvanizing stakeholders to translate policy into action and change

Council on Competitiveness Board and Executive Committee

BOARD

Chairman
Mr. Samuel R. Allen
Chairman and Chief Executive Officer
Deere & Company

University Vice Chairman
Dr. Michael M. Crow
President
Arizona State University

Labor Vice Chairman
Mr. William P. Hite
General President
United Association of Plumbers and Pipefitters

Chairman Emeritus
Mr. Charles O. Holliday, Jr.
Chairman
Royal Dutch Shell, plc

Industry Vice Chairman Emeritus
Mr. Michael P. Splinter
Chairman Emeritus
Applied Materials

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

EXECUTIVE COMMITTEE

Mr. Thomas R. Baruch
Managing Director
Baruch Future Ventures

Dr. Gene D. Block
Chancellor
University of California, Los Angeles

Mr. William H. Bohnett
President
Whitecap Investments LLC

Mr. James K. Clifton
Chairman and CEO
Gallup, Inc.

Dr. John J. DeGioia
President
Georgetown University

Ms. Cathy Engelbert
Chief Executive Officer
Deloitte LLP

Mr. Jeff M. Fettig
Chairman and CEO
Whirlpool Corporation

Dr. William H. Goldstein
Director
Lawrence Livermore National Laboratory

Mr. James S. Hagedorn
Chairman and CEO
The Scotts Miracle-Gro Company

Ms. Sheryl Handler
President and CEO
Ab Initio

The Honorable Shirley Ann Jackson
President
Rensselaer Polytechnic Institute

Dr. Linda P.B. Katehi
Chancellor
University of California, Davis

Dr. Pradeep K. Khosla
Chancellor
University of California, San Diego

Dr. Steven Knapp
President
The George Washington University

Mr. Mario Longhi
President and CEO
United States Steel Corporation

Dr. Thomas E. Mason
Laboratory Director
Oak Ridge National Laboratory

Mr. J.B. Milliken
Chancellor
The City University of New York

Mr. Brian T. Moynihan
Chairman and Chief Executive Officer
Bank of America

The Honorable Janet Napolitano
President
The University of California System—Regents

Dr. Santa J. Ono
President
University of Cincinnati

Dr. Harris Pastides
President
University of South Carolina

Mr. James M. Phillips
Chairman and CEO
NanoMech, Inc.

Mr. Nicholas T. Pinchuk
Chairman and CEO
Snap-on Incorporated

Professor Michael E. Porter
Bishop William Lawrence University Professor
Harvard Business School

Mr. Robert L. Reynolds
President and CEO
Putnam Investments

Mr. Matthew Riddle
President and Chief Executive Officer
Walbro Engine Management

Dr. Kenan E. Sahin
Founder and President
TIAX LLC

Mr. Mayo A. Shattuck, III
Executive Chairman
Exelon Corporation

Dr. Lou Anna K. Simon
President
Michigan State University

Mr. Edward M. Smith
President and CEO
Ullico Inc.

The Honorable Subra Suresh
President
Carnegie Mellon University

Mr. Lawrence Weber
Chairman
W2 Group, Inc.

Ms. Randi Weingarten
President
American Federation of Teachers, AFL-CIO

Dr. W. Randolph Woodson
Chancellor
North Carolina State University

Mr. Paul A. Yarossi
President
HNTB Holdings Ltd.

Dr. Robert J. Zimmer
President
The University of Chicago

Council on Competitiveness Membership

Dr. Joseph E. Aoun
Northeastern University

Dr. Aziz Asphahani
QuesTek Innovations LLC

The Honorable Sandy K. Baruah
Detroit Regional Chamber

Dr. Mark P. Becker
Georgia State University

Ms. Stephanie W. Bergeron
Walsh College

The Honorable Rebecca M. Blank
University of Wisconsin—Madison

Dr. Joel Bloom
New Jersey Institute of Technology

Dr. Lee C. Bollinger
Columbia University

Dr. Mauro Borges Lemos
CEMIG

Dr. Richard H. Brodhead
Duke University

Dr. Robert A. Brown
Boston University

Mr. Al Bunshaft
Dassault Systèmes Americas

Dr. James P. Clements
Clemson University

The Honorable Mitchell E. Daniels, Jr.
Purdue University

Mr. Ernest J. Dianastasis
CAI

Dr. Joseph A. DiPietro
The University of Tennessee

Dr. Nicholas B. Dirks
University of California, Berkeley

Dr. Michael V. Drake
The Ohio State University

Dr. Charlene M. Dukes
Prince George's Community College

Ms. Amy Ericson
Alstom U.S.

Dr. Carol L. Folt
The University of North Carolina at Chapel Hill

Mr. Kenneth C. Frazier
Merck & Co., Inc.

Dr. W. Kent Fuchs
University of Florida

Dr. Sharon Gaber
University of Toledo

The Honorable Patrick D. Gallagher
University of Pittsburgh

Dr. E. Gordon Gee
West Virginia University

Dr. Judy Genshaft
University of South Florida

Dr. Howard Gillman
University of California, Irvine

Mr. Gregory Glaros
SYNEXXUS, Inc.

Mr. Robert Graybill
Nimbis Services, Inc.

Dr. Amy Gutmann
University of Pennsylvania

Mr. Peter T. Halpin
World Resources Company

Dr. Philip J. Hanlon
Dartmouth College

Mr. V. Burns Hargis
Oklahoma State University

Dr. Patrick T. Harker
University of Delaware

Ms. Marillyn A. Hewson
Lockheed Martin

Dr. John C. Hitt
University of Central Florida

Mr. Jeffrey R. Immelt
General Electric Company

Rev. John I. Jenkins
University of Notre Dame

Dr. Robert E. Johnson
Becker College

Dr. Brooks Keel
Georgia Regents University

Mr. David W. Leebron
Rice University

Dr. Laurie Leshin
Worcester Polytechnic Institute

Dr. Michael Lovell
Marquette University

Mr. Bill Mahoney
SCRA

Mr. Sean McGarvey
North America's Building Trades Unions

Dr. Michael A. McRobbie
Indiana University

Dr. Mark Mone
University of Wisconsin—Milwaukee

Dr. H. Keith Moo-Young
Washington State University Tri-Cities

Dr. Mark G. Mykityshyn
Tangible Software Inc.

Dr. M. Duane Nellis
Texas Tech University

Mr. Keith D. Nosbusch
Rockwell Automation, Inc.

Dr. Eduardo J. Padrón
Miami Dade College

Dr. G.P. "Bud" Peterson
Georgia Institute of Technology

Mr. Jonas Prising
ManpowerGroup

Mr. Ajita Rajendra
A.O. Smith Corporation

Dr. Edward Ray
Oregon State University

Dr. L. Rafael Reif
Massachusetts Institute of Technology

Mr. Ralph Resnick
National Center for Defense Manufacturing and Machining

Mr. Rory Riggs
Balfour, LLC

Dr. Jean Robillard
University of Iowa

Dr. Thomas F. Rosenbaum
California Institute of Technology

Mr. Douglas Rothwell
Business Leaders for Michigan

Vice Admiral John R. Ryan USN (Ret.)
Center for Creative Leadership

Dr. Timothy D. Sands
Virginia Polytechnic Institute and State University

Dr. Scott L. Scarborough
University of Akron

Dr. Mark S. Schlissel
University of Michigan

Mr. Paul Scialla
Delos Living LLC

Dr. David E. Shaw
D.E. Shaw Research

Dr. John D. Simon
Lehigh University

Mr. Frederick W. Smith
FedEx Corporation

Mr. Addison Snell
Intersect360 Research

Dr. Elisa Stephens
Academy of Art University

Dr. Elizabeth Stroble
Webster University

Dr. Teresa Sullivan
University of Virginia

Dr. Satish K. Tripathi
State University of New York at Buffalo

Dr. Thomas M. Uhlman
New Venture Partners LLC

Dr. Steven J. Visco
PolyPlus Battery Company

Dr. Jeffrey Wadsworth
Battelle Memorial Institute

Mr. Mark A. Weinberger
EY

Dr. Kim A. Wilcox
University of California, Riverside

Mr. Keith E. Williams
Underwriters Laboratories Inc.

Dr. Mark S. Wrighton
Washington University in St. Louis

NATIONAL LABORATORY PARTNERS

Dr. Steven F. Ashby
Pacific Northwest National Laboratory

Ms. Jill M. Hruby
Sandia National Laboratories

Dr. Martin Keller
National Renewable Energy Laboratory

Dr. Peter B. Littlewood
Argonne National Laboratory

CORPORATE PARTNERS

AT&T Inc.

Citi

Delta Air Lines, Inc.

IBM

Procter & Gamble Co.

United Technologies Corporation

Verizon

NATIONAL AFFILIATES

Ms. Lynn Brickner
ARCS Foundation Inc.

Ms. Molly C. Broad
American Council on Education

Ms. Cathleen A. Campbell
U.S. Civilian Research & Development Foundation

Mr. C. Michael Cassidy
Georgia Research Alliance

Dr. Thomas M. Connelly, Jr.
American Chemical Society

Mr. Jeffrey Finkle
International Economic Development Council

Dr. Norman Fortenberry
American Society for Engineering Education

Mr. Richard Grefé
AIGA

The Honorable Rush Holt
American Association for Advancement of Sciences

Mr. James A. Jefferies
IEEE-USA

Dr. Dominik Knoll
World Trade Center New Orleans

Mr. Jack E. Middleton
SMC3

Lieutenant Colonel Harrison A. Page USMC (Ret.)
Oak Ridge Associated Universities

Dr. Hunter R. Rawlings
Association of American Universities

Mr. Dan Reicher
American Council on Renewable Energy

Dr. Richard M. Soley
Object Management Group, Inc.

Dr. David A. Vogan, Jr.
American Mathematical Society

Council on Competitiveness Distinguished Fellows and Staff

DISTINGUISHED AND SENIOR FELLOWS

The Honorable Erich Bloch
Huron Consulting LLP; and Former Director, National Science Foundation

The Honorable Daniel S. Goldin
Chairman and CEO, The Intellisis Corporation; and Former Administrator, National Aeronautics and Space Administration

The Honorable Bart J. Gordon
Partner, K&L Gates LLP; and Former United States Representative (TN)

Dr. Paul J. Hommert
Former Director, Sandia National Laboratory; and Former President , Sandia Corporation

Dr. Lloyd A. Jacobs
President Emeritus, The University of Toledo

The Honorable Alexander A. Karsner
Chairman and CEO, Manifest Energy LLC; and Former Assistant Secretary for Energy Efficiency and Renewable Energy, U.S. Department of Energy

The Honorable Alan P. Larson
Senior International Policy Advisor, Covington & Burling LLP; and Former Under Secretary of State for Economics, U.S. Department of State

Mr. Alex R. Larzelere
President, Larzelere & Associates LLC; and Former Director, Modeling and Simulation Energy Innovation Hub, Office of Nuclear Energy, U.S. Department of Energy

Mr. Edward J. McElroy
Former Chief Executive Officer, Ullico, Inc.; and President Emeritus, American Federation of Teachers, AFL-CIO

Ms. Michelle Moore
Chief Executive Officer, Groundswell; and Former Senior Advisor to the Director, Office of Management and Budget, Executive Office of the President of the United States

Dr. Luis M. Proenza
President Emeritus, The University of Akron

Dr. Anthony J. Tether
Former Director, Defense Advanced Research Projects Agency, U.S. Department of Defense

Dr. Mohammad A. Zaidi
Member, Strategic Advisory Board, Braemer Energy Ventures; and Former Executive Vice President and Chief Technology Officer, Alcoa, Inc.

SENIOR COUNCIL LEADERSHIP

Deborah L. Wince-Smith
President & CEO

William C. Bates
Executive Vice President and Chief of Staff

Chad Evans
Executive Vice President

Council on Competitiveness
900 17th Street, NW, Suite 700 Washington, D.C. 20006 T 202 682 4292
Compete.org

Compete.

Council on
Competitiveness