



**Compete.**

Council on  
Competitiveness

# BUILD for Advanced Computing

The Final Report in the “NSCI: Advancing  
U.S. Competitiveness through Public-  
Private Partnerships for Advanced  
Computing Initiative”

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# Letter from the President

In November 2018, the Council on Competitiveness (Council) embarked on a new effort with the Joint Program Office (JPO) of the National Strategic Computing Initiative (NSCI) and with support from the National Science Foundation (NSF) to develop and suggest public-private partnership (PPP) concepts the JPO could undertake to ensure further the benefits of NSCI-supported research and development (R&D) will have an enduring positive effect for the United States. This effort, Building University-Industry-Laboratory Dialogues (BUILD) for Advanced Computing, rose from long-standing efforts at the Council to understand and enhance the impact of the nation's advanced computing resources. The rapid proliferation and growing accessibility of advanced computing resources has created an opportunity to build new partnerships and capitalize on areas of the economy that may benefit from these technologies.

With the groundwork set, the Council sought partners across the United States to develop a series of forums in search of new-to-the-world, PPP models enabling America to bolster the value of its R&D and partnerships during the coming decades. The Council was proud to have found partners and co-hosts to establish three dialogues:

- **BUILD 1:** Held at the University of Pittsburgh Campus in Pittsburgh, PA, on November 7, 2018, co-hosted by the Honorable Patrick D. Gallagher, Chancellor, the University of Pittsburgh; and Dr. Farnam Jahanian, President, Carnegie Mellon University.



- **BUILD 2:** Held at the San Diego Supercomputer Center on the University of California San Diego Campus in San Diego, CA, on March 11, 2019, co-hosted by Dr. Pradeep K. Khosla, Chancellor, the University of California San Diego; and Dr. Michael Norman, Director, San Diego Supercomputer Center.
- **BUILD 3:** Held at the University of Texas System in Austin, TX, on May 14, 2019, co-hosted by Mr. James B. Milliken, Chancellor, The University of Texas System.

This report represents a thoughtful synthesis of findings from these three dialogues, an exploration of the role of PPPs in advanced computing across the United States, and an exploration of the emergent PPP concepts resulting from our conversations.

I would like to thank the members of the JPO of the NSCI for their efforts in advancing and amplifying U.S. computing capabilities and global leadership; the National Science Foundation for their support of this critical work; as well as the many experts, and public and private sector representatives, who shared their perspective to shape the recommendations and models captured within this report. I would also like to extend a special appreciation to our partners and hosts of the BUILD Series, for engaging their networks to optimize the potential of this effort and support of the initiative, without which this work would not have been possible.

The Council looks forward to continuing to engage leaders across the United States to marshal resources toward a more productive and prosperous future for America.

Sincerely,

A handwritten signature in black ink that reads "Deborah L. Wince-Smith". The signature is written in a cursive style with a large initial 'D' and 'S'.

**The Honorable Deborah L. Wince-Smith**

President & CEO

Council on Competitiveness

# Summary of Building University-Industry-Laboratory Dialogue (BUILD) Series

The United States has long been at the forefront of computing. The rapid progress of computing technologies has propelled U.S. productivity and competitiveness during the past several decades, but the march of computing progress is slowing.

Other nations have taken notice of the role of computing to advance a nation's productivity and prosperity, and enabled by the continued downward trend of computing costs and shrinking of physical components, many countries are more easily able to leverage HPC to boost native and latent innovation potential. During the past five years, China in particular has leveraged a growing domestic computing industry to capture significant portions of the overall performance capacity and number of HPC systems among the fastest computers in the world.

The Council has long recognized the importance of HPC as a tool for competitiveness, positing that “to out-compute is to out-compete” and launching in 2003 the High Performance Computing Advisory Council and in 2004 the first Council HPC Users Conference to focus on how best to apply the nation's computing resources toward enhancing competitiveness. The Council has continued to make the business and policy case for HPC and advanced computing during the course of the past 15 years, releasing several landmark reports along the way, such as *Solve. The Exascale Effect: The Benefits of Supercomputing Investment for U.S. Industry* in 2014 and *Explore: An Advanced Computing Agenda for Competitiveness* in 2019.

The Council also has a history of examining the structure, objectives and effectiveness of public-private partnerships (PPPs), including a groundbreaking *The Power of Partnerships* report in 2014. This report examined PPPs in the area of clean energy manufacturing, surveying 184 studies, drawing insights from those most relevant, and engaging partnership participants to offer original analysis on partnership models most likely to advance specific objectives. In a similar fashion, this project would examine existing literature on advanced computing partnerships (many developed by the Council), and bring those insights into a series of progressive dialogues to examine what kinds of PPPs for which purposes are needed to build a competitive HPC ecosystem for today.

Building on the Council's history in both the computing and PPP realms, in 2017, the Council was approached to explore ways to improve and expand public-private collaboration in ways that advance HPC technologies that support federal missions in scientific discovery, national security and economic competitiveness. This collaboration is critical for the United States to maintain a modern, competitive HPC ecosystem to develop and deploy the technological capacity, computational foundations and workforce capacity needed to preserve American leadership in advanced computing. In response, the Council launched Building University-Industry-Laboratory Dialogue (BUILD) for Advanced Computing, a progressive dialogue series with the Joint Program Office (JPO) of the National Strategic Computing Initiative (NSCI) to develop and suggest PPP concepts the JPO could undertake to execute Objec-

tive No. 5 of the NSCI—which is the development of PPPs to ensure the benefits of the R&D supported by the NSCI will have an enduring positive effect for national interests, U.S. industry and academia.

During 2018 and 2019, the Council convened public and private sector leaders from industry, companies and private entities at the forefront of computing to surface new PPP models around computing. These included:

- **BUILD 1** in Pittsburgh, PA, on November 7, 2018, co-hosted by the Honorable Patrick D. Gallagher, Chancellor, the University of Pittsburgh; and Dr. Farnam Jahanian, President, Carnegie Mellon University, launched the progressive dialogue series and spent time focused on the applications for advanced computing partnerships in overall computing, health and wellness, and artificial intelligence.
- **BUILD 2** in San Diego, CA, on March 11, 2019, co-hosted by Dr. Pradeep K. Khosla, Chancellor, the University of California San Diego; and Dr. Michael Norman, Director, San Diego Supercomputer Center, began the process of refining new PPP models shared in the first dialogue, and shared deep dives on the use of advanced computing PPPs in the prediction and mitigation of natural disasters, as well as health and wellness.
- **BUILD 3** in Austin, TX, on May 14, 2019, co-hosted by Mr. James B. Milliken, Chancellor, The University of Texas System, further honed PPP models discussed in BUILD 1 and 2, discussed emergent models in the national lab system for HPC PPPs and shared deep dives into real-world PPPs focused on national security and university high performance computing resources.

# BUILD 1— Pittsburgh, PA

# BUILD 1—Participants

## CO-CHAIRS

**Mr. James B. Milliken**  
Chancellor  
The University of Texas System

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

## PARTICIPANTS

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**Dr. Vipin Chaudhary**  
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Hypergiant Sensory Sciences

**Ms. Candy Culhane**  
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Computing Modernization Program  
U.S. Army Engineer Research and Development  
Center

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Executive Vice Chancellor for Academic Affairs  
The University of Texas System

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Senior Scientist, Quantum Information Sciences  
The MITRE Corporation, and  
Research Associate, Department of Physics  
Harvard University

**Dr. Sasikanth Manipatruni**  
Chief Technology Officer  
Kepler Computing

**Ms. Robin Miles**  
Director, High Performance Computing for Energy  
Innovation  
Lawrence Livermore National Laboratory

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Former Vice President and Chief Engineer Baker  
Hughes, a GE company, and  
Senior Fellow  
Council on Competitiveness

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University of Oklahoma

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& Computational Sciences  
Oak Ridge National Laboratory

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Austin Site Lead  
Google

**Mr. Joshua Oswald**  
Policy Analyst  
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Senior Manager, Global Linux and Government  
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Deputy Director, Commander's Action Group  
Army Futures Command

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Associate Vice President for Research  
The University of Texas at Austin, and  
Executive Director  
Texas Advanced Computing Center

**Mr. Sridhar Sudarsan**

Chief Technology Officer  
SparkCognition

**Dr. Neil Thompson**

Research Scientist, MIT Computer Science  
and Artificial Intelligence Laboratory  
Massachusetts Institute of Technology, and  
Visiting Professor, Lab for Innovation Science  
Harvard University

**Ms. Kathy Trimble**

Advisor  
Joint Staff, U.S. Department of Defense

**Dr. Mark Woodmansee**

Senior Director  
Halliburton Digital Solutions

# BUILD 1—Agenda

## MORNING

### 8:30 Registration and Light Breakfast

### 9:00 Welcome Remarks and Roundtable Introductions

**Mr. James B. Milliken**  
Chancellor  
The University of Texas System

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

In this session, following opening remarks, participants will introduce themselves and offer—in a lightning round—a one-minute reason for their interest and engagement in the dialogue.

Possible questions for participants to consider in framing their opening, one-minute statements:

- What is the most significant challenge to the research, development and deployment of critical computing assets in your company, organization, industry?
- What does the term “advanced computing” mean to you and your organization?
- How are you currently leveraging advanced computing assets in your business and organization?

### 9:45 What Is the National Strategic Computing Initiative—and its Key Goals?

**Dr. Vipin Chaudhary**  
Program Director, Office of Advanced  
Cyberinfrastructure  
National Science Foundation

**Mr. Chad Evans**  
Executive Vice President  
Council on Competitiveness

### 10:00 Bridging from BUILD 1 and 2 in Pittsburgh and San Diego—A Deep Dive into Potential PPP Models to Advance the Future of Microelectronics

#### PPP CONCEPT 1

**Dr. Neil Thompson**  
Research Scientist, MIT Computer Science and  
Artificial Intelligence Laboratory  
Massachusetts Institute of Technology, and  
Visiting Professor, Lab for Innovation Science  
Harvard University

**11:00 Continued...A Deep Dive into Potential  
PPP Models to Advance the Future of  
Microelectronics**

**PPP CONCEPT 2**

Presenter

**Mr. Dan Armbrust**  
Co-Founder and Director  
Silicon Catalyst

Kickoff Discussants

**Mr. Jim Brinker**  
President  
Intel Federal LLC

**Mr. Anthony Kenisky**  
Sr. Account Manager  
Cray

**AFTERNOON**

**12:00 Lunch**

**Keynote Address**

**Ms. Alexandra Landsberg**  
Deputy Director, DoD High Performance Computing  
Modernization Program  
U.S. Army Engineer Research and Development  
Center

**LTC Cade Saie**  
Chief, Data Analytics  
Army Futures Command

**Mr. Bryan Port**  
Deputy Director, Commander's Action Group  
Army Futures Command

**1:00 Starting a New Computing Ecosystem:  
A View from Industry**

As the arc of historic productivity gains and rapid technological advancement in traditional computing power begins to sunset, how can new computing ecosystems compete to power the next generation of innovation?

**Dr. Sasikanth Manipatruni**  
Chief Technology Officer  
Kepler Computing

### 2:00 **Scaling a Successful PPP: Lessons from the HPC4EI Experience**

Lawrence Livermore National Laboratory has fostered an innovative program to encourage the use of high performance computing resources across a variety of industry sectors. Can the nation scale this program's model to include other departments, agencies and stakeholders?

#### **Presenter**

**Ms. Robin Miles**

Director, High Performance Computing for Energy Innovation  
Lawrence Livermore National Laboratory

#### **Kickoff Discussant**

**Mr. Rick Arthur**

Senior Director  
GE Research

### 3:00 **Coffee Break**

### 3:30 **Assessing Local Strengths and Capabilities: The TACC Story**

How is the Texas Advanced Computing Center designing and operating some of the world's most advanced computing resources?

- What PPP models work in the TACC ecosystem?
- What are the near and long-term opportunities facing TACC?

**Dr. Dan Stanzione**

Associate Vice President for Research  
The University of Texas at Austin, and  
Executive Director  
Texas Advanced Computing Center

### 4:30 **Scanning The Frontiers of Advanced Computing: AI and Beyond**

What higher order possibilities and competitive advantage can advanced computing—such as AI—deliver for the United States?

As advanced computing resources mature, their use cases will expand. What new opportunities will advanced computing make available that current computing sources cannot accommodate?

#### **Kickoff Discussants**

**Mr. Sridhar Sudarsan**

Chief Technology Officer  
SparkCognition

**Mr. Dave Copps**

CEO  
Hypergiant Sensory Sciences

**Ms. Irene Qualters**

Associate Laboratory Director for Simulation and  
Computation  
Los Alamos National Laboratory

**Ms. Candy Culhane**

Program/Project Director  
Los Alamos National Laboratory

**5:15 Closing Comments and the Path Forward**

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

**6:00 Reception Hosted by UT System****Chancellor James B. Milliken at the Bauer  
House, the Official Residence of the UT  
System Chancellor**

Transportation will be available between the AT&T Executive Conference Center and the Bauer House, the official residence of the Chancellor of the UT System. Shuttle service will make two trips between the AT&T Executive Conference Center and the Bauer House—the first trip starting at 5:30

**7:30 Reception Ends**

Transportation will be available from the Bauer House back to the AT&T Executive Conference Center at the end of the reception. Shuttle service will make two trips between the Bauer House and the AT&T Executive Conference Center beginning at 7:30.

# BUILD 1—Pittsburgh, PA

BUILD 1, held at the University of Pittsburgh, convened several dozen public and private-sector leaders at the forefront of advanced computing to discuss stakeholder motivations around new-to-the-world models for PPPs in the advanced computing space. As the initial dialogue, participants were socialized to the intent of the BUILD Series, as well as the role of the Joint Program Office of the National Strategic Computing Initiative. With this baseline set, participants were able to leverage their expertise toward the creation of new PPPs.

To supplement the conversation and bring added context to the potential for PPPs to have real-world impact advanced computing, dialogue participants also engaged in sector deep dives, focusing attention on discrete elements of the economy.

## Deep Dives

### Computing and Information Technology

A PPP is defined by stakeholders involvement, not topic area or scope of work. This means PPPs can be formed at the broadest scale, attracting a critical level of stakeholders and high-level grand challenges. PPPs may also be formed to focus on tightly bound, project- or technology-focused issues. In this deep dive, participants discussed the fear of some in the room that such specialization may also lead to fragmentation across PPPs, creating competition across PPPs—which is not necessarily problematic—and restricting data sharing and providing mechanisms to develop standards that ensure quality—which is problematic. In response, deep dive leaders advocated for keeping PPPs at a high level to bring together the widest array of stakeholders and encourage sharing amongst participating individuals and organizations.



*Dr. Rob Rutenbar, Senior Vice Chancellor for Research, University of Pittsburgh; Dr. Farnam Jahanian, President, Carnegie Mellon University; Ms. Rebecca Bagley, Vice Chancellor for Economic Partnerships, University of Pittsburgh; The Honorable Patrick D. Gallagher, Chancellor, University of Pittsburgh; and Mr. Chad Evans, Executive Vice President, Council on Competitiveness.*

Broad PPPs that can attract a critical level of stakeholders are necessary, meaning new PPPs should be focused around key, high-level grand challenges—as opposed to specializing—which could lead to fragmentation. It is also extremely important to encourage data sharing and provide mechanisms to develop standards that ensure quality.

### Health and Wellness

Health and wellness was identified as an area of significant potential for advanced computing, with participants engaging in a robust discussion surrounding the trends of healthcare's increased integration with information technology systems, enabling a higher quantity and quality of data captured for analysis, as well as making more information available to providers across the healthcare space for better patient outcomes. However, participants were also quick to note the need for reformation to realize the potential



*Dr. Nick Nystrom, Interim Director, Pittsburgh Supercomputing Center, addresses attendees during roundtable introductions.*

of advanced computing in the healthcare space.

Through conversation, participants surfaced six “T”s critical to PPP success in this area:

- **Technology**—New technologies disrupt the current market for the delivery of healthcare through the development of new medications, delivery systems, and symptom analysis for better diagnoses. In addition, new technologies enable new business models, leading to the “consumerization” of the overall healthcare space to focus on patient needs, as well as opening new opportunities for patients to take greater ownership over their healthcare.
- **Timing**—Healthcare research and technology lifecycles have differing horizons of viability. Any PPP will have to define the scope of work and timeline for the particular research intent or commercial market.
- **Talent**—The lack of qualified engineers and scientists equipped to develop and deploy advanced computing solutions and maintain up-to-date skills and domain knowledge, especially in the healthcare space, will impact the potential of healthcare to develop far into the future.
- **Transformation**—The market must be open to change, or any PPP will not find success.
- **Translation**—Often the domain of the entrepreneur and technology transfer organizations, the impact of any discovery, innovation or technology only extends as far as it can successfully move from foundational science to practical application.
- **Trust**—Personal Identifying Information, Protected Health Information and other patient data privacy concerns must be dealt with thoughtfully before such data is used en mass.

### Artificial Intelligence

Discussion amongst participants turned to the influence of artificial intelligence on the economy, specifically related to the incentives driving firms to participate in national research. Firms conducting in-house research use deep learning algorithms to generate a competitive advantage in the marketplace relative to peer firms through the creation, collection, curation and consumption of vast data sets.

Having undertaken the financial and time-intensive burden of this process, private sector organizations may be hesitant to share models and lessons learned with a country-wide, scaled research effort, and may choose to maintain exclusive rights to their models themselves. However, this area is ripe for pre-competitive research to move the industry forward without making redundant the efforts of individual firms.

# BUILD 2— San Diego, CA

# BUILD 2—Participants

## CO-CHAIRS

### Dr. Sandra A. Brown

Vice Chancellor for Research and Distinguished Professor  
University of California, San Diego

### Dr. Michael Norman

Director  
San Diego Supercomputer Center

### The Honorable Deborah L. Wince-Smith

President & CEO  
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Chief Technology Officer  
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Program/Project Director  
Los Alamos National Laboratory

### Mr. Gora Datta

Board Member  
IEEE Southern California Council

### Dr. James Davis

Vice Provost, Information Technology & Chief Academic Technology Officer  
University of California, Los Angeles

### Ms. Angela Phillips Diaz

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University of California, San Diego

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Director, National Energy Research Scientific Computing Center  
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### Mr. Chad Evans

Executive Vice President  
Council on Competitiveness

### Mr. Mark Field

Chief Technology Officer and Vice President  
Thermo Fisher Scientific

### The Honorable Daniel Goldin

Former Administrator  
NASA

### Dr. Tami Grimmett

High Performance Computing Software Consultant  
Group Lead  
Idaho National Laboratory

### Dr. Susan Hackwood

Professor of the Graduate Division  
University of California, Riverside, and Former Executive Director  
California Council on Science and Technology

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### Dr. Bruce Hendrickson

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Lawrence Livermore National Laboratory

### Mr. Kevin Jameson

HPC Federal Accounts Manager  
HPE

### Mr. Ian Kerman

Director, BIOVIA Innovation Lab  
Dassault Systèmes

### Dr. Rob Knight

Faculty Director, Center for Microbiome Innovation  
University of California, San Diego

### Ms. Jennifer Landress

Senior Vice President and Chief Operating Officer  
Biocom

### Dr. Edlyn Levine

Senior Scientist, Quantum Information Sciences  
The MITRE Corporation, and Research Associate, Department of Physics  
Harvard University

### Dr. G.P. Li

University of California, Irvine Division Director  
California Institute for Telecommunications and Information Technology (Calit2)

### Dr. Sasikanth Manipatruni

Chief Technology Officer  
Kepler Computing

### Mr. Joshua Oswalt

Policy Analyst  
Council on Competitiveness

### Dr. Manish Parashar

Office Director, Office of Advanced Cyberinfrastructure  
National Science Foundation, and Co-Chair, Joint Program Office for Strategic Computing

### Mr. Has Patel

Founder  
Infologic

### Dr. Michael Pazzani

Vice Chancellor for Research and Economic Development  
University of California, Riverside

### Dr. Albert Pisano

Dean, Jacobs School of Engineering  
University of California, San Diego

### Dr. Guna Rajagopal

Vice President, Computational Sciences  
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University of California, Irvine Applied Innovation

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Artificial Intelligence Laboratory  
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Harvard University

**Ms. Kathy Trimble**

Advisor  
Joint Staff, U.S. Department of Defense

**Dr. Gilroy Vandentop**

Director, Corporate University Research  
Intel

**Ms. Julie Meier Wright**

Former Chief Executive, San Diego Regional  
Economic Development Corporation; Former First  
Secretary of Trade & Commerce, State of California,  
and Senior Fellow, Council on Competitiveness

**Major General Sheila Zuehlke**

U.S. Air Force (retired)

# BUILD 2—Agenda

## MORNING

### 8:30 Registration and Light Breakfast

### 9:00 Welcome Remarks and Roundtable Introductions

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

**Dr. Michael Norman**  
Director  
San Diego Supercomputer Center

**Dr. Sandra A. Brown**  
Vice Chancellor for Research and Distinguished Professor  
University of California, San Diego

In this opening session, participants will introduce themselves and offer—in a lightening round—a one-minute reason for their interest and engagement in the dialogue.

Possible questions for participants to consider in framing their opening, one-minute statements:

- What is the most significant challenge to the research, development and deployment of critical computing assets in your company, organization, industry?
- What does the term “advanced computing” mean to you and your organization?
- How are you currently leveraging advanced computing assets in your business and organization?

### 10:15 What Is the National Strategic Computing Initiative—and its Key Goals

**Dr. Manish Parashar**  
Office Director, Office of Advanced Cyberinfrastructure  
National Science Foundation, and  
Co-Chair  
Joint Program Office for Strategic Computing

### 10:30 Coffee Break

### 10:45 Lessons from BUILD 1 & Setting the Stage—Understanding Public-Private Partnership (PPP) Models and Success Factors

Research by the Council on Competitiveness has characterized globally successful PPP models in four broad categories: Early Market; Mature Market; Test Bed/Demonstration; and Innovation Network. While neither definitive or exhaustive, each of these four models offers a “lens” through which participants can focus ideas on how to think about shaping a PPP.

Following a brief stage setting, the dialogue will take a series of sectoral “deep dives” to explore possible PPP concepts.

**Mr. Chad Evans**  
Executive Vice President  
Council on Competitiveness

**11:00 Bridging from BUILD 1 in Pittsburgh—  
A Deep Dive into Potential PPP Models  
to Advance the Future of Microelectronics**

**PPP CONCEPT 1**

**Dr. Neil Thompson**  
Research Scientist, MIT Computer Science and  
Artificial Intelligence Laboratory  
Massachusetts Institute of Technology, and  
Visiting Professor, Lab for Innovation Science  
Harvard University

**AFTERNOON**

**12:00 Lunch Break and Data Center Tours**

**1:15 Continued...A Deep Dive into Potential  
PPP Models to Advance the Future of  
Microelectronics**

**PPP CONCEPT 2**

**Dr. Ramamoorthy Ramesh**  
Purnendu Chatterjee Endowed Chair in Energy  
Technologies, Department of Materials Science  
& Engineering  
University of California, Berkeley

**2:00 Roundtable Review and Refine**

This session will be a moderated conversation to review the specific PPP models presented to address a major, national grand challenge—the future of the microelectronics industry’s computing R&D needs—and discuss how to craft these ideas into formal concepts.

Topics of discussion will focus on PPP issues like: mission/vision, organization/structure, governance, finance, success metrics, etc.

**Dr. Albert Pisano**  
Dean, Jacobs School of Engineering  
University of California, San Diego

**2:30 Coffee Break**

**2:45 Novel Application of Advanced  
Computing Research and an Opportunity  
for a New Public-Private Partnership:**

**Lessons from California in Predicting and  
Mitigating Natural Disasters**

**Dr. Larry Smarr**  
Director  
California Institute for Telecommunications and  
Information Technology (Calit2)

**4:00 PPP Deep Dive: Health and Wellness**

**Dr. Guna Rajagopal**  
Vice President, Computational Sciences  
Janssen

**Dr. Amoolya Singh**  
Vice President, R&D  
Amyris, Inc.

**5:00 Closing Comments and The Path Forward**

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

**Dr. Michael Norman**  
Director  
San Diego Supercomputer Center

**5:15 Closing Reception**

**6:15 Reception Ends**

## BUILD 2—San Diego, CA



*Mr. Chad Evans, Executive Vice President, Council on Competitiveness; Dr. Michael Norman, Director, San Diego Supercomputer Center; Dr. Sandra A. Brown, Vice Chancellor for Research and Distinguished Professor, University of California, San Diego; Dr. Albert Pisano, Dean, Jacobs School of Engineering, University of California, San Diego; The Honorable Deborah L. Wince-Smith, President & CEO, Council on Competitiveness.*



*Dr. Manish Parashar, Office Director, Office of Advanced Cyberinfrastructure, National Science Foundation, and Co-Chair, Joint Program Office for Strategic Computing.*

BUILD 2, held at the San Diego Supercomputer Center on the University of California San Diego Campus in San Diego, CA, brought together more than four dozen national and local computing and PPP experts to bring new perspectives to the discussion started at BUILD Series launch in Pittsburgh, PA.

Participants discussed the runway still possible for partnerships to advance computing technologies and sectors of the U.S. economy that might benefit from increased application of HPC, even absent the slowing productivity growth of general computing resources. Notably, conversation related much of this potential to the context of global competition with China, a nation whose close relationship between the public and private sector operates in effect as

an economy-wide PPP. Conversation also focused on the importance of education and introducing students to advanced computing at a young age.

### Deep Dives

#### **Prediction and Mitigation of Natural Disasters**

Participants heard from a member of the WIFIRE Laboratory at the University of California Institute for Telecommunications and Technology, which is using advanced computing technologies to monitor environmental conditions in real time using drones and providing early warning to emergency services and wildfire prevention agencies. The drones generate data for WIFIRE's large models to best determine where wildfires may occur, as well as to improve drone deployment and coordination.

## **Health and Wellness**

Building on the potential for advanced computing in health and wellness started in BUILD 1, participants looked toward applications in drug discovery and biotechnology. Key to progress in this field is data sharing by government agencies—such as the National Institutes of Health—to model, simulate and validate the effectiveness of new pharmacotherapy, lowering costs and accelerating time to market for new medications, as well as pairing government agencies and research institutes to integrate big data and cloud analytics into research studies. Importantly, this would also lower the cost of long-term research in the field, supporting higher fidelity, more granular models capable of anticipating the effect of new medicinal treatments.

Dialogue participants identified examples from both deep dives as potential PPP models for semiconductor development, also raising the importance of standards that would allow disparate collections of data/databases to communicate more easily. This would, in turn, help to lower the barriers to using data across disciplines, domains and industries.

# BUILD 3— Austin, TX

# BUILD 3—Participants

## CO-CHAIRS

**Mr. James B. Milliken**  
Chancellor  
The University of Texas System

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

## PARTICIPANTS

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Silicon Catalyst

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Senior Director  
GE Research

**Mr. Michael Bernstein**  
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**Mr. Jim Brinker**  
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**Mr. Dave Copps**  
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Hypergiant Sensory Sciences

**Ms. Candy Culhane**  
Program/Project Director  
Los Alamos National Laboratory

**Dr. Jim Davis**  
Vice Provost, Information Technology  
& Chief Academic Technology Officer  
University of California, Los Angeles

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Distinguished Professor and Qualcomm Endowed  
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HPE

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The University of Texas System

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Senior Scientist, Quantum Information Sciences  
The MITRE Corporation, and  
Research Associate, Department of Physics  
Harvard University

**Dr. Sasikanth Manipatruni**  
Chief Technology Officer  
Kepler Computing

**Ms. Robin Miles**  
Director, High Performance Computing for Energy  
Innovation  
Lawrence Livermore National Laboratory

**Mr. Rustom Mody**  
Former Vice President and Chief Engineer Baker  
Hughes, a GE company, and  
Senior Fellow  
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Director, OU Supercomputing Center for Education  
& Research (OSKER)  
University of Oklahoma

**Dr. Jeff Nichols**  
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& Computational Sciences  
Oak Ridge National Laboratory

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Austin Site Lead  
Google

**Mr. Joshua Oswald**  
Policy Analyst  
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**Mrs. Krystal Patel**  
Senior Manager, Global Linux and Government  
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Army Futures Command

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Associate Dean for Research, College  
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Associate Agency Director for Strategic Initiatives  
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Texas Advanced Computing Center

**Mr. Sridhar Sudarsan**

Chief Technology Officer  
SparkCognition

**Dr. Neil Thompson**

Research Scientist, MIT Computer Science  
and Artificial Intelligence Laboratory  
Massachusetts Institute of Technology, and  
Visiting Professor, Lab for Innovation Science  
Harvard University

**Ms. Kathy Trimble**

Advisor  
Joint Staff, U.S. Department of Defense

**Dr. Mark Woodmansee**

Senior Director  
Halliburton Digital Solutions

# BUILD 3—Agenda

## MORNING

### 8:30 Registration and Light Breakfast

### 9:00 Welcome Remarks and Roundtable Introductions

**Mr. James B. Milliken**  
Chancellor  
The University of Texas System

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

In this session, following opening remarks, participants will introduce themselves and offer—in a lightning round—a one-minute reason for their interest and engagement in the dialogue.

Possible questions for participants to consider in framing their opening, one-minute statements:

- What is the most significant challenge to the research, development and deployment of critical computing assets in your company, organization, industry?
- What does the term “advanced computing” mean to you and your organization?
- How are you currently leveraging advanced computing assets in your business and organization?

### 9:45 What Is the National Strategic Computing Initiative—and its Key Goals?

**Dr. Vipin Chaudhary**  
Program Director, Office of Advanced  
Cyberinfrastructure  
National Science Foundation

**Mr. Chad Evans**  
Executive Vice President  
Council on Competitiveness

### 10:00 Bridging from BUILD 1 & 2 in Pittsburgh and San Diego—A Deep Dive into Potential PPP Models to Advance the Future of Microelectronics

#### PPP CONCEPT 1

**Dr. Neil Thompson**  
Research Scientist, MIT Computer Science and  
Artificial Intelligence Laboratory  
Massachusetts Institute of Technology, and  
Visiting Professor, Lab for Innovation Science  
Harvard University

**11:00 Continued...A Deep Dive into Potential  
PPP Models to Advance the Future of  
Microelectronics**

**PPP CONCEPT 2**

Presenter

**Mr. Dan Armbrust**  
Co-Founder and Director  
Silicon Catalyst

Kickoff Discussants

**Mr. Jim Brinker**  
President  
Intel Federal LLC

**Mr. Anthony Kenisky**  
Sr. Account Manager  
Cray

**AFTERNOON**

**12:00 Lunch**

**Keynote Address**

**Ms. Alexandra Landsberg**  
Deputy Director, DoD High Performance Computing  
Modernization Program  
U.S. Army Engineer Research and Development  
Center

**LTC Cade Saie**  
Chief, Data Analytics  
Army Futures Command

**Mr. Bryan Port**  
Deputy Director, Commander's Action Group  
Army Futures Command

**1:00 Starting a New Computing Ecosystem:  
A View from Industry**

As the arc of historic productivity gains and rapid technological advancement in traditional computing power begins to sunset, how can new computing ecosystems compete to power the next generation of innovation?

**Dr. Sasikanth Manipatruni**  
Chief Technology Officer  
Kepler Computing

### 2:00 **Scaling a Successful PPP: Lessons from the HPC4EI Experience**

Lawrence Livermore National Laboratory has fostered an innovative program to encourage the use of high performance computing resources across a variety of industry sectors. Can the nation scale this program's model to include other departments, agencies and stakeholders?

#### **Presenter**

**Ms. Robin Miles**

Director, High Performance Computing for Energy Innovation  
Lawrence Livermore National Laboratory

#### **Kickoff Discussant**

**Mr. Rick Arthur**

Senior Director  
GE Research

### 3:00 **Coffee Break**

### 3:30 **Assessing Local Strengths and Capabilities: The TACC Story**

How is the Texas Advanced Computing Center designing and operating some of the world's most advanced computing resources?

- What PPP models work in the TACC ecosystem?
- What are the near and long-term opportunities facing TACC?

**Dr. Dan Stanzone**

Associate Vice President for Research  
The University of Texas at Austin, and  
Executive Director  
Texas Advanced Computing Center

### 4:30 **Scanning The Frontiers of Advanced Computing: AI and Beyond**

What higher order possibilities and competitive advantage can advanced computing—such as AI—deliver for the United States?

As advanced computing resources mature, their use cases will expand. What new opportunities will advanced computing make available that current computing sources cannot accommodate?

#### **Kickoff Discussants**

**Mr. Sridhar Sudarsan**

Chief Technology Officer  
SparkCognition

**Mr. Dave Copps**

CEO  
Hypergiant Sensory Sciences

**Ms. Irene Qualters**

Associate Laboratory Director for Simulation and  
Computation  
Los Alamos National Laboratory

**Ms. Candy Culhane**

Program/Project Director  
Los Alamos National Laboratory

**5:15 Closing Comments and the Path Forward**

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

**6:00 Reception Hosted by UT System****Chancellor James B. Milliken at the Bauer  
House, the Official Residence of the UT  
System Chancellor**

Transportation will be available between the AT&T Executive Conference Center and the Bauer House, the official residence of the Chancellor of the UT System. Shuttle service will make two trips between the AT&T Executive Conference Center and the Bauer House—the first trip starting at 5:30

**7:30 Reception Ends**

Transportation will be available from the Bauer House back to the AT&T Executive Conference Center at the end of the reception. Shuttle service will make two trips between the Bauer House and the AT&T Executive Conference Center beginning at 7:30.

## BUILD 3—Austin, TX



*All attendees outside of The AT&T Conference Center, where BUILD 3 was hosted on the campus of The University of Texas at Austin.*

BUILD 3, held at the University of Texas System in Austin, TX, brought together nearly 50 national and regional leaders from the advanced computing space to surface new models for PPPs and refine those discussed in previous BUILD events. Similar to the first two BUILD conversations, participants were given a broad overview of the JPO and NSCI's mission and objectives, and quickly updated on the PPP models proposed in previous sessions.

Notably, participants and conversation focused more heavily on the technology and intellectual property of advanced computing—specifically threats to America's competitiveness from China's flood of resources to HPC components and innovations, as well as concerns surrounding the security of America's intellectual property. Participants noted that in

a highly globalized information network—and with domestic value creation centers funded by foreign entities—creating trusted supply chains entirely within U.S. borders is increasingly difficult. The result is a shrinking pool of players in the U.S. market capable of delivering secure advanced computing resources, necessitating PPPs as a means to incent, develop and deliver productivity-enhancing computing products to market.

In considering PPP models proposed during BUILD 1 and 2, participants were less focused on avoiding potential pitfalls that may cause the PPPs to fail and instead were more focused on identifying public sector partners whose mission and interests are most in alignment. Beyond potential partners mentioned in previous conversations, participants also suggested

**PPP HIGHLIGHT****University of Texas San Antonio****National Security Collaboration Center**

The University of Texas San Antonio is leveraging their top-ranked cybersecurity program to build a new government-university-industry partnership—the National Security Collaboration Center—aimed at producing multidisciplinary cyber research and workforce development by bringing together public and private sector leaders to identify current and future needs to enhance the nation's cybersecurity.

<https://www.utsa.edu/strategicplan/tactical-initiatives/nsccl/>



*The Honorable Deborah L. Wince-Smith, President & CEO, Council on Competitiveness; and Mr. James B. Milliken, Chancellor, The University of Texas System.*

the U.S. Trade Representative (USTR) and U.S. Department of Commerce (DoC) as relevant to this space given their experience in the development of SEMATECH, a PPP launched in 1987 between U.S. government agencies and information technology companies to combat the loss of U.S. competitiveness in the semiconductor space. Conversation also raised immigration as a concern, noting that the U.S. must continue to attract skilled engineers and scientists lest computing innovations be produced in other nations outside the bounds of a U.S.-trusted environment.

This focus on security served as a launching point for the day's deep dives.

**Deep Dives****National Security**

Recognizing the importance of HPC to advance defense activities, the DoD, U.S. Army Corps of Engineers, Engineer Research and Development Center Information Technology Laboratory has established the DoD High Performance Computing Modernization Program (HPCMP). The HPCMP supports all DoD services and agencies enhancing science and technology, test and evaluation, and acquisition engineering functions in the defense space, leveraging a series of DoD supercomputing resource centers (DSRCs)—with expertise from partners in other federal agencies, academia and industry—to deliver new and expanded capabilities.

## University High Performance Computing Resources

The University of Texas System and Texas Advanced Computing Center (TACC) is home to Frontera—the fifth fastest supercomputer in the world (at the time of publication)<sup>1</sup>—brought to life by a \$60 million grant from the National Science Foundation in 2018.<sup>2</sup> Leaders from TACC shared their experience working alongside multiple industry partners. They noted that, currently, software and time represented the greatest inhibitors to maximizing the impact of advanced computing. The rapid development of general computing has not adequately incentivized the development of software to exploit processor capacity.

1 [Top500.org](https://www.top500.org/).

2 [Frontera, A new NSF-Funded Petascale Computing System. TACC.](https://www.tacc.utexas.edu/news/2018/08/frontera-a-new-nsf-funded-petascale-computing-system)

# Key Findings from the BUILD Series

# Executive Summary

Advanced computing holds an opportunity to unleash latent innovation potential in the U.S. economy by applying new tools, perspectives and resources to existing problems. Yet, America, and computing in general, sit at a unique moment in time where advances in generalized computing are slowing, business models surrounding technology investments are changing, and both the public and private sector are searching for ways to continue to push productivity with no clear or reliable technology-specific solution on the horizon.

Though the stated goal of the progressive BUILD Series was meant to elicit new-to-the-world PPP models to advanced computing technologies in the United States, conversation among participants raised a number of important policy issues, through which the Council identified recommendations to catalyze advanced computing PPPs in the United States.

## Technology Readiness

Participants generally agreed that no current technology in development is poised to replace the current computing technology paradigm and drive the next generation of advanced computing driven productivity growth. Why? One of the most significant reasons is that the overall pool of investment in this space is much too small.<sup>3</sup> In addition, the diversity of potential technologies has fractured funding sources, extending the time for companies to coalesce around a suite of technologies representing next generation hardware and software. While important to explore all avenues, this extended timeline creates

a time-bound economic imperative: Without new, marketable technologies to fund operations at existing fabrication companies, there may be no domestic industry left to compete when technology representing the next S-curve ascends in the market.

**Recommendation:** The United States must fund both PPPs to support existing market needs and offer economic incentives to rebuild the technology manufacturing sector.

## Filling Gaps Between Specializations

The breadth of the U.S. innovation ecosystem has pushed stakeholders toward increasing levels of specialization, fragmenting and silo-ing many cooperative research efforts.

**Recommendation:** Tie public-sector PPP funding to cross-domain, cross-sector efforts to maximize innovation potential and impact.

## National Security Restrictions Limiting Access to Unrelated Tools for Innovation

The United States has significant institutional research capabilities in its national laboratories, many of which are applied to sensitive research related to national security. This places additional barriers and security measures over all work and facilities at the national laboratory enterprise, creating additional hurdles that may discourage potential partnerships with outside entities.

**Recommendation:** Bring more resources “outside the fence” to lower the barriers to new partnerships and incentivize local growth.

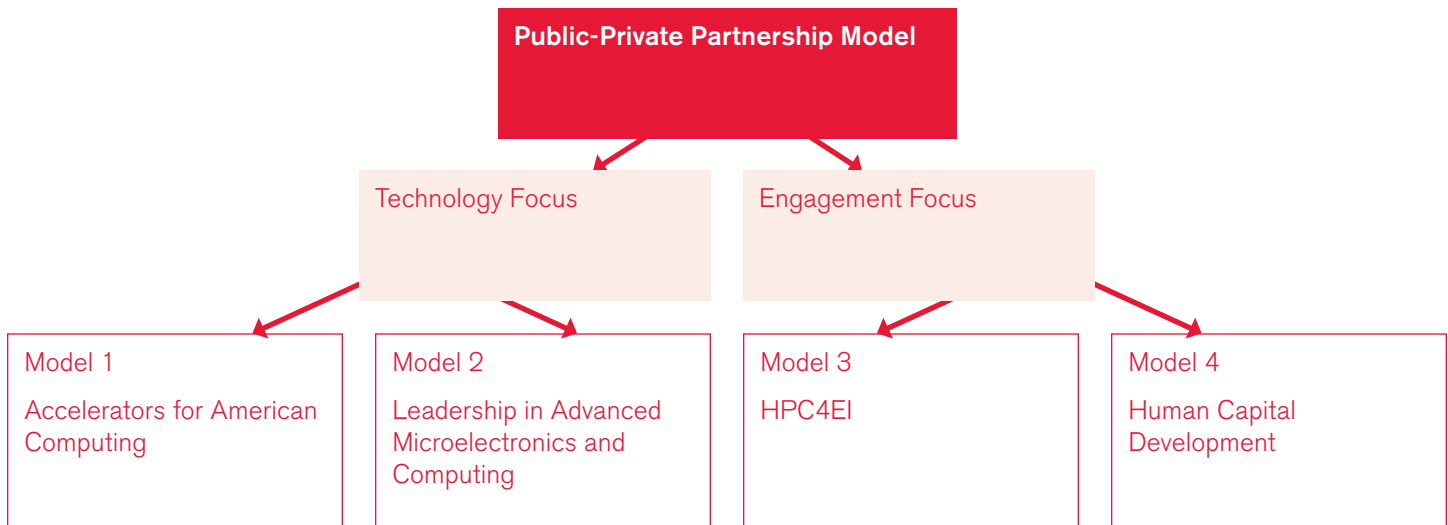
3 See <https://www.nature.com/articles/s41928-017-0005-9>.

## Connectivity

U.S. telecommunications infrastructure needs to be upgraded to enable more reliable and productive engagement.

**Recommendation:** Dedicate funding or create incentives through tax rebates for industry to build a more robust data infrastructure across the United States.

Emerging from the BUILD Series were also several new PPP models that can be carried out by the JPO, with or without support from the Council, to increase the competitiveness of the U.S. advanced computing ecosystem.



# Public-Private Partnerships: A Framework

PPPs provide a valuable mechanism of joint, inclusive action by bringing together government, industry, academia and the national laboratories in developing next-generation, revolutionary technologies relating to advanced computing. These innovative models allow for a multitude of funding sources directed into sustainable solutions for public and private needs.

While organizations through partnerships share resources, they also share potential risks and rewards from the development of the product. Partners are able to hold each other accountable. The best elements and comparative advantages of both sides are brought to the table. Private industry provides an ability to act efficiently in the development of the products while governmental bodies are able to institute standards of knowledge and resources to complete the project and lead it towards public use. There is a significantly higher chance that projects operating under a PPP model will more likely meet cost and schedule objectives.<sup>4</sup>

In previous reports and research, the Council characterizes PPPs across four models. Rather than a strict categorization, the Council suggests PPPs should be characterized by the predominant focus of each PPP, although each may also have characteristics of fit within multiple models:

- Early Market
- Mature Market
- Test Bed/Demonstration
- Innovation Network

**Early Market PPPs** tend to focus predominantly on research for technologies that are less established in the market and/or have few mature firms able or willing to support a PPP on their own. Some Early Market PPPs also engage in prototyping and early commercialization activities.

*Structure:* Early Market PPPs are typically governed by a board that includes university, industry and government representatives. Lab or university personnel are usually responsible for the day-to-day operations rather than an employee of an independent organization.

*Finance:* Early Market PPPs usually rely on federal seed funding to start and some rely in part on annual government funding. Some procure matching funds from industry or fulfill fee-for service contracts.

**Mature Market PPPs** seek to advance the objectives of more mature industries. These PPPs tend to be industry-led and focus on pre-competitive research, cooperative research on advanced manufacturing technologies or standards development. The technologies addressed by these PPPs can be early stage or more mature but are characterized as Mature Market if mature companies exist in the marketplace and engage heavily in the development and execution of product development.

*Structure:* Mature Market PPPs usually establish an independent entity governed by a board of mainly corporate representatives. These PPPs often have a scientific advisory board staffed by member companies and tend to include representatives across supply chains.

4 "Public-Private Partnerships: Benefits and Opportunities for Improvement Within the United States." Syracuse University. 2017. <http://eng-cs.syr.edu/wp-content/uploads/2017/04/P3Report.pdf>.

**Finance:** Government typically, but not always, supplies seed money and research grants. Four of the six Mature Market PPPs the Council examined in the Power of Partnerships report received state funding on an annual basis. As the PPP becomes established, companies tend to contribute most of the funding through a system of membership dues.

**Test Bed/Demonstration PPPs** focus predominantly on testing and demonstration—often working to establish the market for an emerging technology or group of technologies. Although the other PPP models in this study may include testing and demonstration components, the Test Bed / Demonstration PPPs have testing and demonstration as their primary function. These PPPs tend to be local by nature—utilizing the local community for testing purposes—even if their user community is national or global in scope

**Structure:** Test Bed / Demonstration PPPs are usually administered either by organizations contracted by government to operate them or by nonprofits established by members participating in the PPP. The leadership of the PPPs in the Council's Power of Partnerships study varied between industry, academia, laboratories and nonprofits. They also tend to have close working relationships with local governments and economic development authorities.

**Finance:** Government typically provides seed funding for Test Bed / Demonstration PPPs, often including resources to purchase equipment. Federal, state and local governments sometimes continue to provide annual financial support after establishment. Fees-for-services make up the other primary revenue stream.

**Innovation Network PPPs** are generally national or international networks of applied research and demonstration organizations, often focused on a particular technology or set of technologies at each node in the network. The network nodes are sometimes linked by a broad theme, such as cyberinfrastructure with Extreme Science and Engineering Discovery Environment (XSEDE), which substantially enhance the productivity of a growing community of scholars, researchers and engineers through access to advanced digital services that support open research through NSF funding.<sup>5</sup>

**Structure:** A nonprofit organization, overseen by a board of industry and academic representatives, typically governs the day-to-day activities. The nonprofit is often a research institute or a network of institutes. Because of the network characteristic, these PPPs are often decentralized and sometimes the nodes of the network are autonomous, though related.

**Finance:** Governments typically provide a significant share of the seed money—often 50 percent or more. Governments also supply research grants. Of 5 European Innovation Network PPPs, for example, all receive regular annual funding from the government and are commonly considered to be strategic national innovation infrastructure for applied research. Innovation Network PPPs also supplement their budgets through contracted R&D with industry or fee-for-service contracts for industry researchers to use lab infrastructure.

5 XSEDE. 2018. <https://www.xsede.org/>

### Public-Private Partnership Characteristics

1. Model Type
2. Technology Areas
3. Mission
4. Mission Type (sector specific, regional specific, national, international)
5. Focus Areas (production, standards, demonstration, enabling technology, etc.)
6. Governance
7. Organization Model (501C3, LLC, 501C6, etc.)
8. Partners Involved (industry, academic institutions, government agencies, laboratories, etc.)
9. Level of Government Involvement (levels of government involved and their involvement, seed funding, etc.)
10. Funding Stream (membership fees, fee-for-service, state, federal, etc.)
11. Original Funders (total scale of investment and public-private ratio)
12. Motivation and Key Actors in Standing-Up Partnership
13. IP Management
14. Metrics of Success
15. Location
16. Number of Years the PPP Has Operated
17. Key Factors that Drive Success
18. Cost (will this partnership reduce technology and/or structural costs)
19. Innovation (how does this partnership encourage innovation)
20. People/Workforce (will we have a better trained workforce because of this partnership)
21. Demand (does this partnership increase demand for products)
22. Leveling the Playing Field (does this partnership level the playing field for clean energy products)
23. Leadership (does this partnership create leadership that will attract manufacturing)

### Characteristics of PPPs

There are many challenges and barriers that must be overcome and managed to ensure successful collaboration. Effort must be made to bring teams together and understand the goals, expectations, and capabilities of all stakeholders. Each partner also has limits of their own and boundaries they will not cross, sometimes causing conflict amongst those involved. Partnerships are formed due to the complexity of a project which may continue to be difficult even with partners.

To combat many issues with PPPs, a clear legal framework and strategy meetings must be set up to understand the role of each partner. In 2013, the Council released *The Power of Partnerships*, a report on PPPs and examined what makes them successful through dialogues with C-suite executives of major corporations and government leaders.

The Council uncovered several success factors in our conversations with PPP leaders that apply to multiple models. Common success factors include:

- Strong leadership;
- A clear, compelling mission;
- Early funding stream to establish the PPP, usually from the public sector;
- Intellectual property practices that attract corporate participation;
- Participation across industry value chains;
- Engagement by multiple large companies;
- Affordable membership terms for small companies;
- Regional organization or other mechanisms to engage entrepreneurs and the risk capital community;
- Talent development;
- Universities and institutions with a culture of applied research;
- Demonstrably positive community impact;
- Acceptance of high failure rates for new firms and products; and
- Establishment or enhancement of standards, as needed.

When done correctly, the synergy between public and private partners will utilize the strengths of both to produce new innovative models and products that improve society and the economy.

# New Models for Public-Private Partnerships in the Advanced Computing Space

## PPPs to Advance Computing Technologies

Computing and the rapid development of general computing technologies has been a significant driving force behind economic growth in the United States and around the world over the past 50 years. In the past 45 years alone, one third of labor productivity improvements have come from the advancement and influence of information technology.<sup>6</sup> Much of this would have been impossible without exponential advancements in semiconductor computer chips, which over the same period have become orders of magnitude faster, smaller, more power-efficient and less expensive.

This rapid increase in semiconductor productivity is captured in Moore's Law, an observation from co-founder of Fairchild Semiconductor Laboratory and Intel Corporation, Gordon E. Moore, that the number of transistors on a microchip doubles every year or two. Tightly correlated to Moore's Law is Dennard scaling, which explains that as transistors get smaller, they can be run faster. This evolution toward faster, more powerful computers has led to semiconductors entering into every corner of the economy, creating a technology platform that compounds its impact with each successive generation. At the same time, the rapid development and proliferation of semiconductors fostered a global semiconductor fabrication industry, creating an environment of competition and cooperation. However, this decades-long period of innovation and evolution is coming to an end.

The pace of improvement in semiconductors has been slowing since Dennard scaling ended in 2005<sup>7</sup> and is now a faint echo of what it once was (Figure 1).<sup>8</sup> Processor speeds have stagnated, and the replacement cycles for chips are lengthening, suggesting that the current technology is reaching its limits.

But, if current computing technologies are reaching the end of their S-curve (Figure 2)—signifying the maturation and impact of a technology paradigm—this will cause problems throughout the computing ecosystem.

## Fabricating Semiconductors

The end of Moore's Law arises from the difficulty of cheaply and consistently producing smaller transistors on a microchip at scale. In the early 2000s, semiconductors were fabricated at a 130 nm scale, with 25 companies capable of producing semiconductor chips at scale. Over time, transistors continued to shrink and their manufacture became more difficult and costly, such that by 2015, only four companies were able to produce cutting-edge processors at scale (Figure 3).

As the cost of cutting-edge semiconductor manufacturing has grown, it has diminished competition and edged out a number of U.S.-based fabricators. This is having significant impacts on national competitiveness—creating the technology tools that drive productivity—and on national security—maintaining a

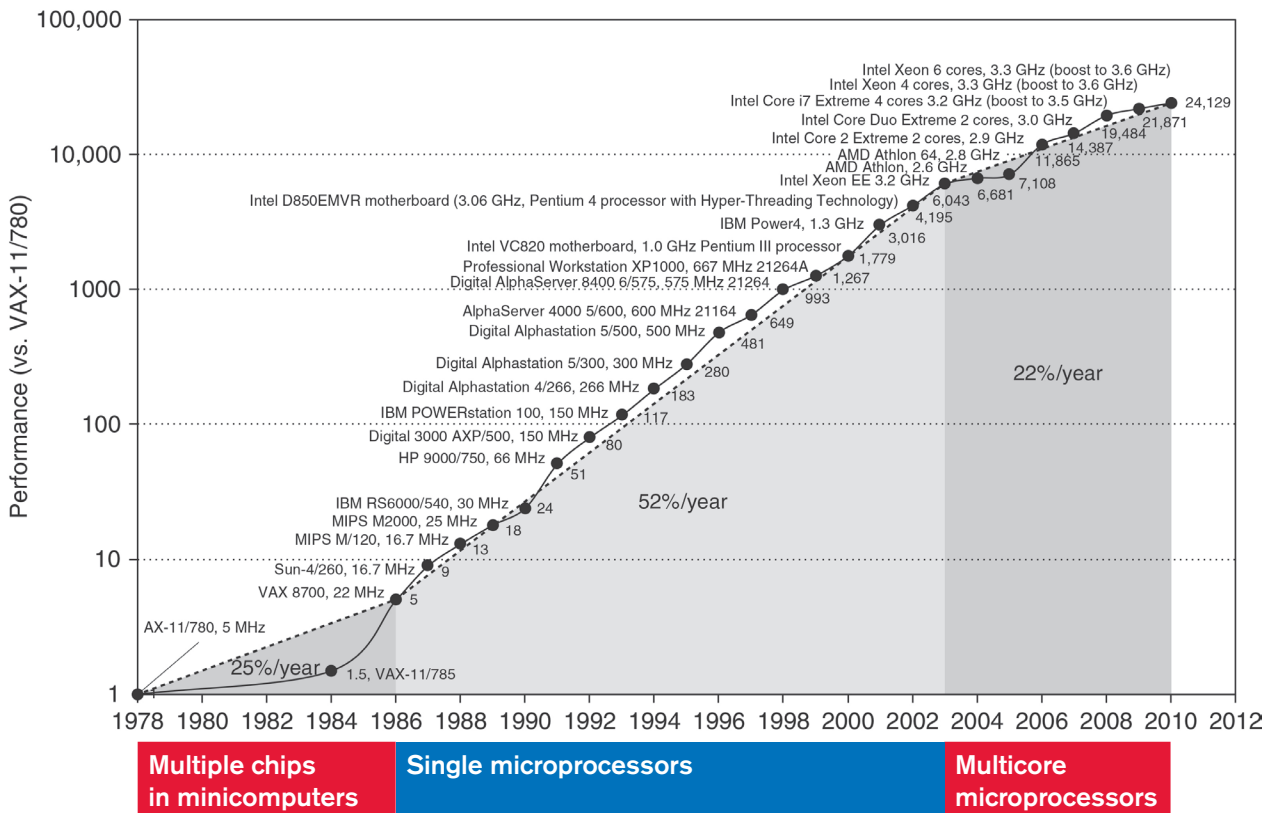
6 Byrne, Oliner and Sichel (2013).

7 <https://www.micron.com/about/blog/2018/october/metamorphosis-of-an-industry-part-two-moores-law>.

8 John L. Hennessy, and David A. Patterson. "Domain Specific Architectures," in *Computer architecture: a quantitative approach*, Sixth Edition, Elsevier, 2018.

**Figure 1. Computing Performance Improvement Slowing (SPECint Benchmark)**

Source: Hennessy, JL, and Patterson, DA. *Computer Architecture, A Quantitative Approach, Fifth Edition*. Morgan Kaufmann Publishers Inc., 2012.



domestic supply chain for the design, manufacture and distribution of technology for defense and critical infrastructure within the United States.

### Scaling Becomes More Expensive

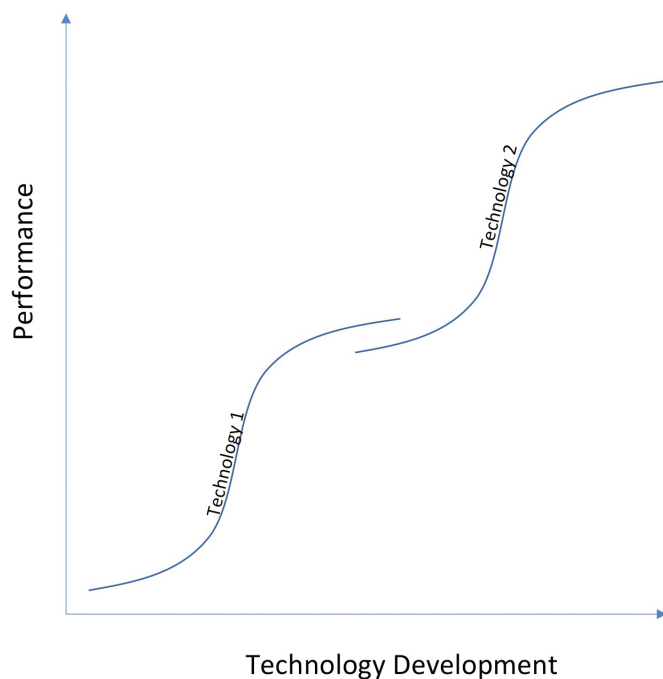
The rise of compute-heavy applications across the economy and injection of computers into everyday devices driving the Internet of Things (IoT) both demand aggressive growth in computing resources. Historically, scaling-up happened inexpensively because the Moore's Law enhancements in computing technology did not drive up chip cost. Today, absent this beneficial contribution, scaling up com-

puting power also means scaling up the cost of that computing power, making it much less economically advantageous.

Currently, there is no next-generation computing technology ready for broad market adoption that can replace the current computing standard and thus usher in a jump to the next S-curve and power a renewed wave of productivity. Recognizing that work must be done to augment current computing technology to return to a pathway of speed

## Figure 2. S-curves Representing Technology Maturation Pathways

Source: Dr. Neil Thompson, MIT



increases while also charting a path to a new computing archetype, two PPP models emerged from the BUILD Series to overcome the declining growth from slowing computing technology advancement, each identifying new and distinct tranches of productivity growth achieved through leveraging public and private sector expertise.

### MODEL: Accelerators for American Computing

**Identified Problem:** The slowing advancement of general computing technologies has slowed productivity growth and caused a breakdown in new technology investment lifecycle

**PPP Solution:** Promote the development of a broad portfolio of specialized hardware to extend the ability of existing semiconductor manufacturing facilities to fuel widespread American productivity gains.

Moore's Law has been powered by an economic cycle,<sup>9</sup> where increasingly broad adoption of processors by users finances the investments needed to deliver faster, more efficient transistors (Figure 4). But this also runs in reverse. When technical improvements slow, fewer new users adopt, which leads to fewer resources to fund the R&D activities. And so, as this economic cycle winds down, so do chip improvements.<sup>10</sup> (Figure 1.)

Previously, when one computing technology plateaued, the industry would move to the next S-curve, from relays to vacuum tubes to transistors to integrated circuits. But today, with no successor

9 Bresnahan and Trajtenberg, 1992.

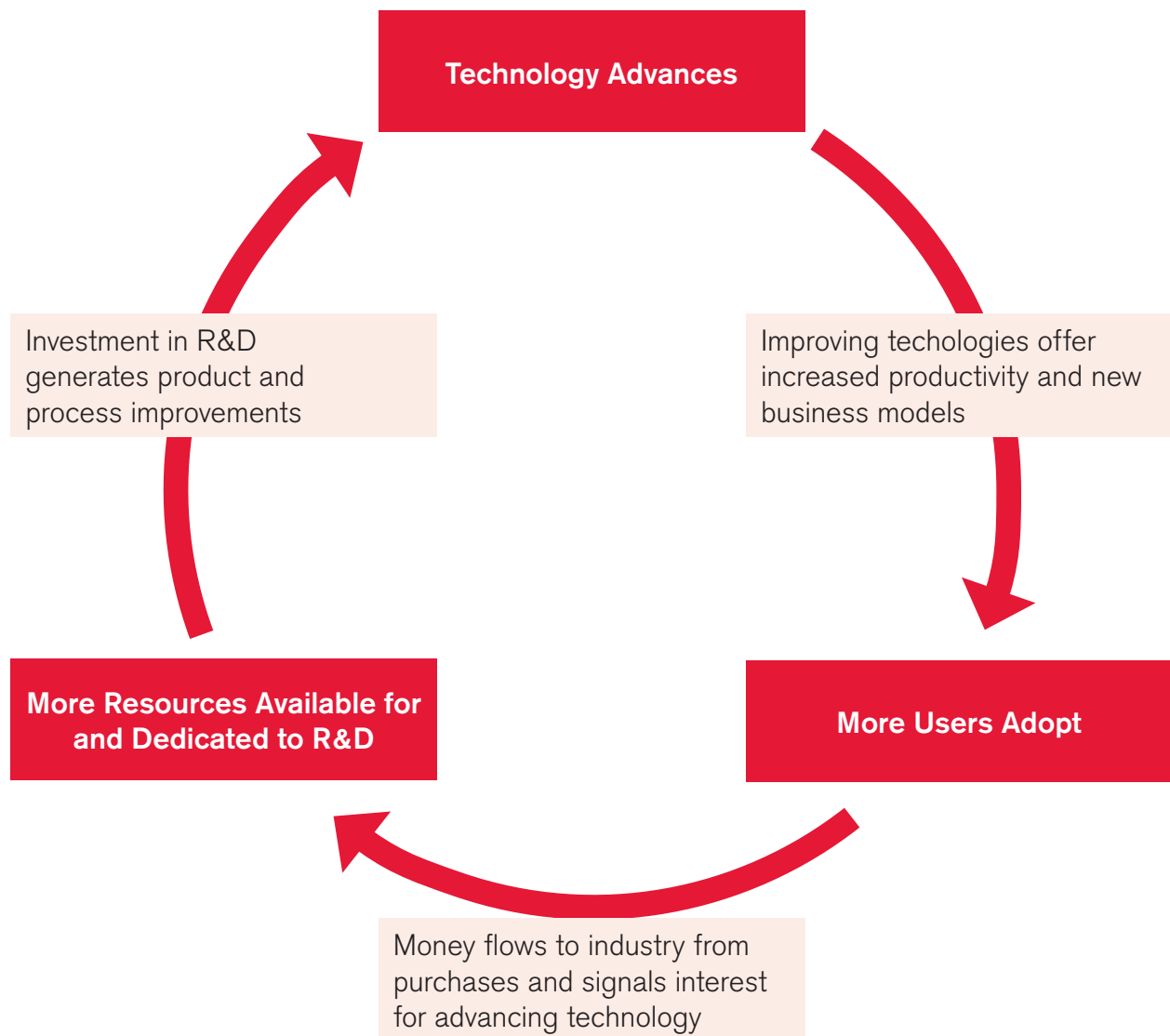
10 Thompson and Spanuth, 2020.



#### Figure 4. General Technology Cycle

Source: Dr. Neil Thompson, MIT

General purpose technologies are supported by three “legs”, for which the failure of one “leg” would result in a failure of the entire system.



computing technology ready for broad commercialization, the industry and the nation must find ways to squeeze more out of current computing technologies. Here, machine learning—and the proliferation of specialized chips for it—can be a guide. In the past, the advancement of general computing technologies progressed at such speed that there was not time for most specialized processors to pay off their development costs before new general-purpose chips eclipsed their performance and stole their market—and so many either were not developed or failed quickly. However, the slowing improvements to CPUs are re-invigorating these business models, making them economically viable investments. For those companies who specialize, it can extend their S-curve away from the plateau of general purpose processors' moribund gains and extend a bridge to the next computing technology S-curve (Figure 5).

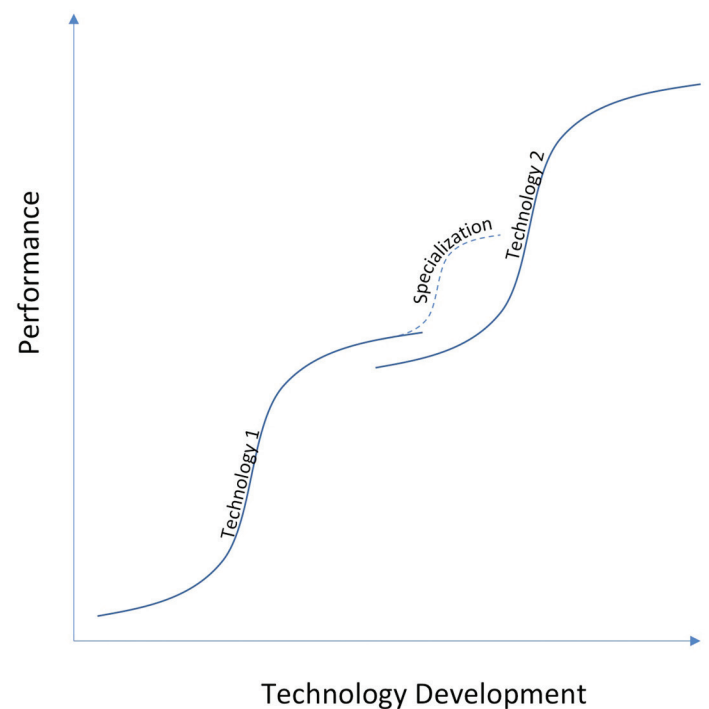
The proposed PPP, **Accelerators for American Computing**, engages stakeholders across the public and private sectors to identify opportunities for this computing evolution.

The lack of a PPP in this space will not halt development of specialized chips. Rather, the computing ecosystem has already started on the path of bespoke computing systems for use in compute-intensive environments, such as the upper-echelon of HPC, cryptocurrency and artificial intelligence, among others. However, this dawning fragmentation of processors is currently limited to organizations able to afford the significant costs of developing a new processor and adapting software to use it, which will eventually cleave computing into a fast-lane—accessible to those with the resources to invest—and a slow lane—for everyone else whose computing needs or algorithms are not deemed to

### Figure 5. S-curves Representing Technology Maturation Pathways—and the Role of Specialization to Bridge Pathways

Source: Dr. Neil Thompson, MIT

S-curves representing technology maturation pathways, with a dotted-line representing the added potential for more effectively using an existing technology as a bridge to the next technology.



be of the highest industrial or economic value. The purpose of this PPP is to minimize this separation, nurturing the development and commercialization of several intellectual property and computing resource models with the greatest benefit to the U.S. economy overall.

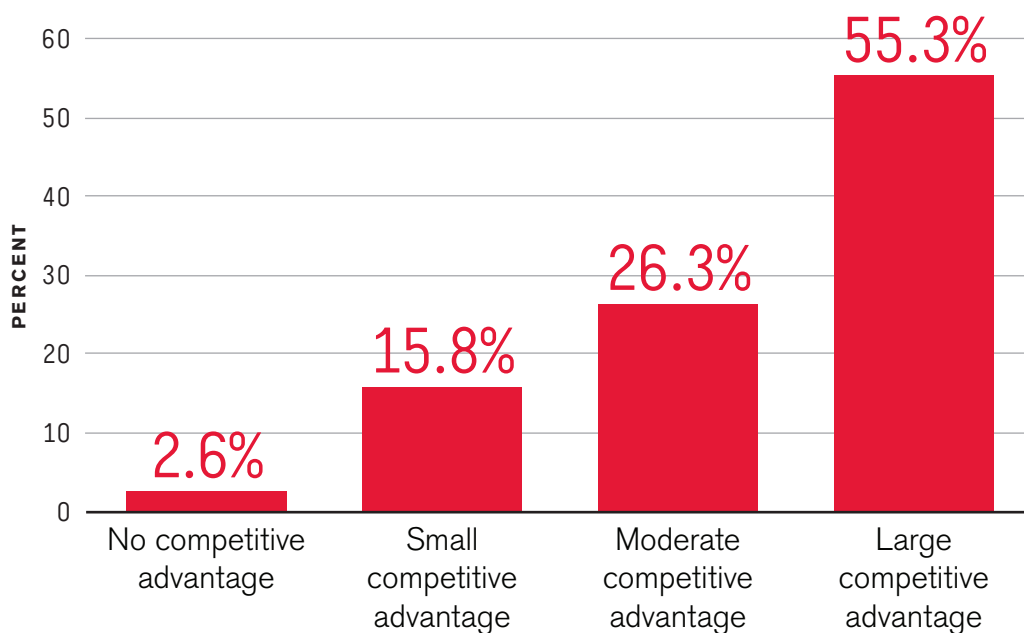
**Next Steps:** To further refine this model, the Council partnered with Dr. Neil Thompson at the Massachusetts Institute of Technology to survey the nation's computing leaders in business, national laboratories and universities. More than 40 organizations participated, and their responses paint a clear picture of the national competitiveness challenge that slower U.S. progress in hardware has brought, and of the need for specialized chips to help address it.

For these leading organizations, computing is a central part of how they compete. When asked what effect a “moderate” computing advantage gave them, 55 percent said a “large” competitive advantage, and 26 percent a “moderate” competitive advantage (Figure 6.). So, for them, to “out-compute” really is to “out-compete.”

Organizations are already pursuing computing speed-ups from specialized hardware (e.g. GPUs) as Moore's Law has slowed. In the past five years, the share of computing that the surveyed organizations are doing on these specialized chips has increased by 150 percent, and they now devote 14 percent of their I.T. developer time to adopting existing accelerators.

### Figure 6. A Moderate Computing Advantage Yields...

Source: Advanced Computing Survey, undertaken by the Council on Competitiveness and Dr. Neil Thompson, MIT, Spring 2020.



**Despite this rapid growth in the importance of specialized chips, there remains an important gap that this PPP would fill.** Only 40 percent of organizations said that their most important type of calculation was what today's main specialized chips were designed for. For the other 60 percent, there is an opportunity to build chips that will make them more productive. And this will probably need to be done by external bodies, such as this PPP is proposing, because only six percent of organizations were devoting a substantial share of their internal developers to designing new chips for themselves. And, of course, one would expect this to be even lower for the users of computing in the broader economy who are less technically sophisticated than the firms surveyed. And so, **there is a large opportunity for the proposed PPP to capture the computing needs of the country and build the hardware that will help them bridge the gap before a Moore's Law successor technology appears.**

**The survey results not only paint a clear picture of the important role that computing plays for U.S. competitiveness, but also for China's competitiveness, and China is scaling up its investments in this area much faster.** Despite the firms in the sample being computing leaders in the United States, 42 percent said that their Chinese competitors already had better computational capabilities than they do, and 79 percent said their Chinese competitors were improving faster. **So the rationale for these specialized chips is not just national prosperity, but also national security and competitiveness.**

The next steps to make this PPP a reality will be to broaden this survey to include more of the key players in the national economy and national priorities, and to work with hardware experts so that a portfolio of specialized hardware accelerators can be identified that will provide the most benefit to the country.

#### MODEL: Accelerators for American Computing

Steps/Responsibility	Public	Private
Identify the most valuable industrial and economic algorithms	✓	
Validate a shortlist of accelerators that will have the biggest impact	✓	✓
Design and build specialized processors		✓
Design and create easy-to-use interfaces	✓	✓
Engage the private sector broadly to enhance adoption		✓

## MODEL: Leadership in Advanced Microelectronics and Computing

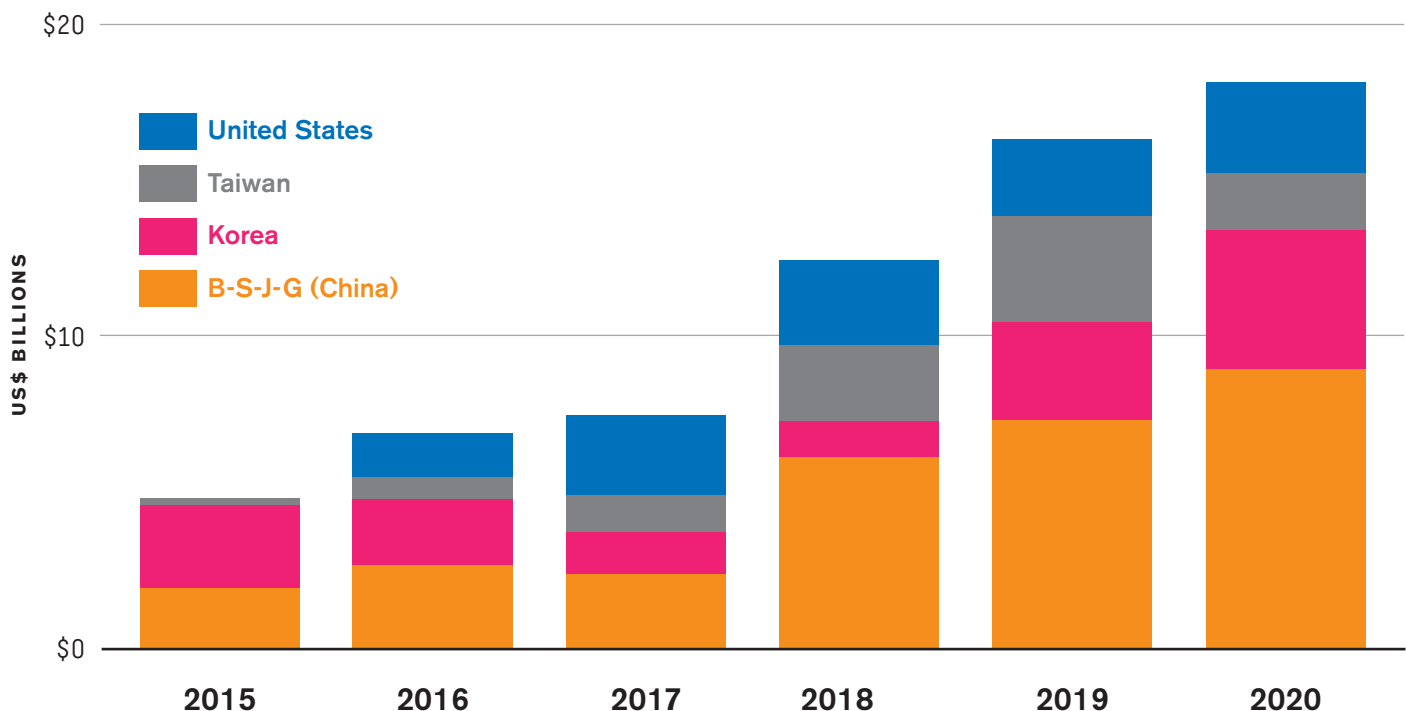
**Identified Problem:** Small companies are able to partner or get funding for early-stage R&D and chip designs ready for the market. However, there is a middle area where new chip designs are dying, potentially hurting the future of the U.S. semiconductor industry and hope for new processor technology. Companies are having a very hard time in the middle, where they need to scale.

**PPP Solution:** Co-design computing technology development with heavy industry involvement and improve the ability to scale promising technology to de-risk industry involvement.

The semiconductor supply chain was formerly vertically integrated under a single device manager. The industry has now fractured, with firms focused on discrete elements of chip design, manufacture and assembly. This fragmentation thinned out the market for fabrication, eventually culling the number of companies with leading edge fabrication facilities (Figure 3). The consolidation of semiconductor manufacturing has also resulted in a consolidation of seed money for new ventures, making it difficult for small companies with new technologies to find the resources necessary to scale. As a result, the large system companies, such as IBM, Apple, Google and Facebook, are not able to find semiconductors

**Figure 7. China Fab Spending by Company Headquarter Region**

Source: SEMI ([www.semi.org](http://www.semi.org)), *China IC Industry Outlook Report*



to meet their needs and are now moving into building their own semiconductors. Similar trends exist in China for firms such as Baidu, Huawei and Xiaomi.

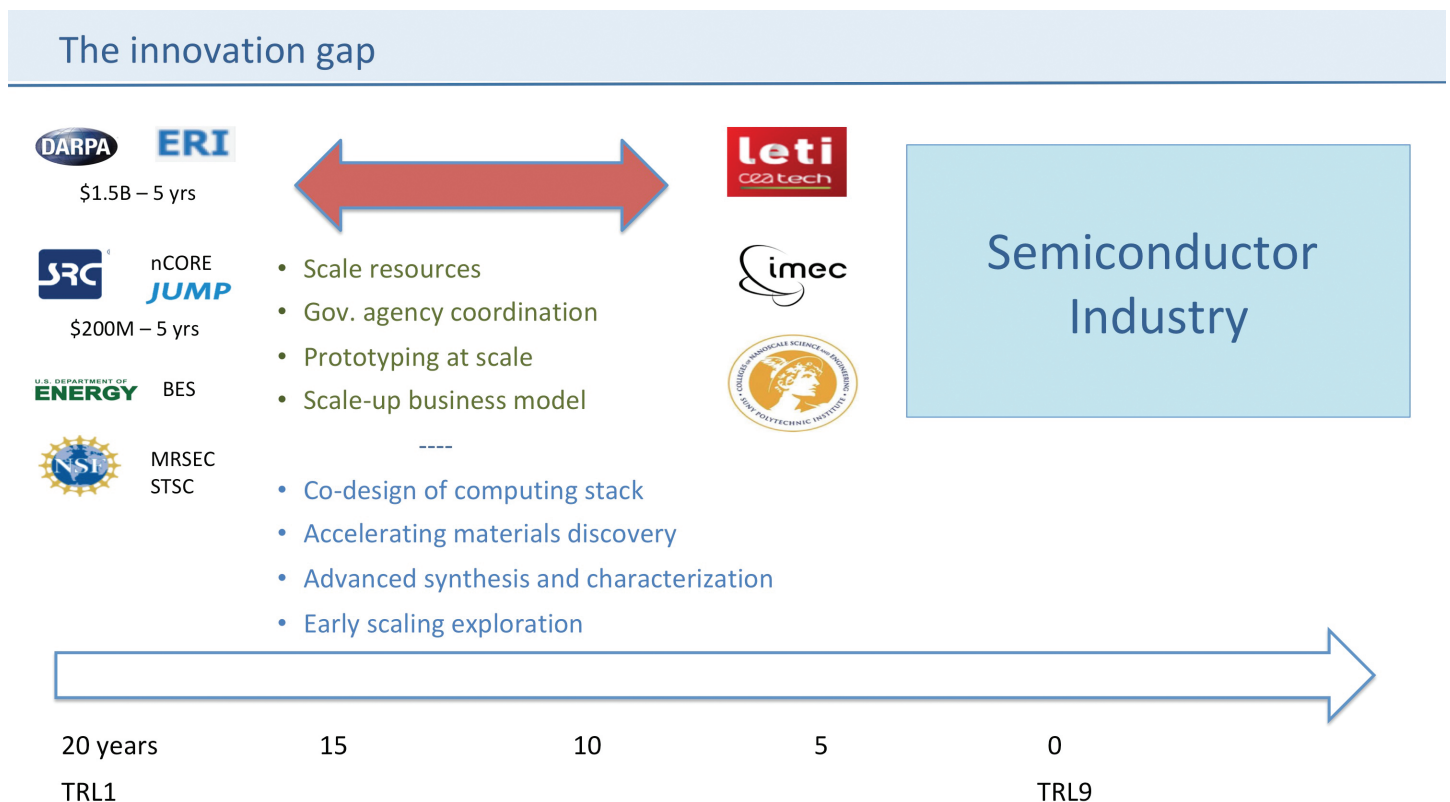
Currently, China consumes >60 percent of chips, yet produces <15 percent. China's response is "Made in China 2025," which aims to produce domestically 40 percent by 2020 and 70 percent by 2025, backed by \$150B central and provincial investment. China is, in effect, one large PPP and is able to apply significant resources—such as investment funds, M&A, government procurement and other incentives—to build the semiconductor industry. In the

past five years, China's investment in semiconductor fabrication has risen significantly, while the United States has barely moved the needle. The United States needs to make a larger investment in building domestic capacity for the design, manufacture and distribution of microelectronics and the building blocks of advanced computing.

This issue of scaling new technologies is the core element of this PPP model. Resources are being poured into basic research for new technologies by the government and applied research is funded by industry for deployable technology. However, there is

**Figure 8. Innovation and funding gap between 5-15 year time horizon**

Source: Armbrust, Daniel and Ramesh, Ramamoorthy. *Leadership in Advanced Microelectronics and Computing*. May 2019. PowerPoint Presentation.



no investable mechanism to scale flowering technologies on accelerated (relative to current) timelines.

In response, the PPP proposes leveraging the funding and research capabilities of the federal government, technology accelerator programs and startups from academia, and market and scalability knowledge from industry to continually prioritize promising candidate technologies. Ideally, doing so will de-risk promising new technologies to the point that America's industry is sufficiently capable and confident in a given technology's future to bring it to market.

This will require an national approach, relying on the unique and diverse strengths inherent to regions around the country to focus on advances and alternatives to current semiconductor technologies. By co-designing and prioritizing promising candidate technologies for the next generation of computing technologies, performing necessary research and demonstrating scalability with deep industry engage-

ment, new innovations will have addressed industry concerns about technology gaps with sufficient de-risking to incentivize private sector investment.

### PPPs to Advance Computing Users and Goods

Consistent technological progress is a core element of continued productivity growth through advanced computing. However, the human element driving technological progress and creatively applying computing to new problems cannot be overlooked. Through the course of these dialogues, as well as previous Council initiatives operating in similar domains, the Council has learned there is a lack of awareness of computing resources in the United States, the ability of these computing resources to significantly augment the competitiveness of many areas of the American economy, and how advanced computing resources can be effectively leveraged.

#### MODEL: Leadership in Advanced Microelectronics and Computing

Steps/Responsibility	Public	Private
Co-design computing stack	✓	✓
Access to user facilities		✓
Prototype	✓	✓
Fund Innovation Centers		✓

Two new PPPs focused around the user rather than developing new technology emerged during the conversations, highlighting the range and types of engagements necessary bolster advanced computing partnerships in the United States.

## MODEL: HPC4EI

**Identified Problem:** Companies are not using HPC as aggressively as possible.

**PPP Solution:** Advance America's energy and manufacturing agenda through the deployment and use of high performance computing, modeling and simulation capabilities across industry. In essence, scale nationally—across different government agencies—the successful, DOE-housed **HPC4 Energy Innovation Initiative (HPC4EI)**, and partner with industry to lower the risk of HPC adoption, leveraging best-in-class supercomputers, unique software and SMEs to overcome problems in industries like steel making, and refining (from paper and pulp, to petroleum).

High performance computing is an important tool for innovators, researchers and manufacturers, reducing time lost through trial and error to optimize innovation through modeling and simulation. The effectiveness of these efforts is proportional to their fidelity and granularity, requiring accurate physics supported by powerful AI data analysis to perform complex work only capable on high performance computers. However, effectively leveraging this tool to solve difficult problems requires significant resources to build and operate, and expert staff to design and model programs.

Lawrence Livermore National Laboratory (LLNL) recognized how its resources—HPC resources and staff, as well as deep expertise in a variety of subject matter domains—could be leveraged to enhance

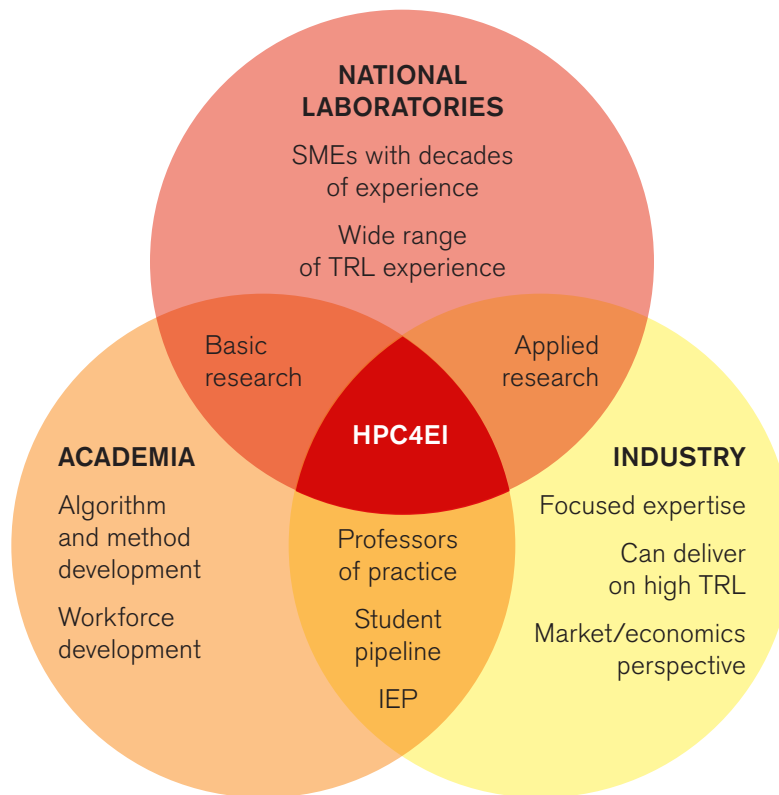
## Why HPC?

High performance machines are able to run higher quality models and simulations faster than conventional machines people have at home or work. Conventional machines may not have the computing power to be time or cost efficient within a given time horizon to capture market attention.

American industry output and improve overall U.S. competitiveness, with significant benefits for both parties.

LLNL built and piloted a PPP to serve these goals, calling it the HPC4EI. The key idea is to de-risk private sector research, design and development efforts by providing a globally unparalleled innovation infrastructure (distinctive computing power coupled with distinctive human resource engagement and support) that many companies and even industries cannot replicate themselves. (Figure 9). National Laboratories have subject matter experts with decades of experience and have worked with a wide range of TRLs. Industry brings to the PPP focused expertise and experience delivering high TRLs, as well as a market and economics perspective to solution development. Universities can train the next generation of computing and subject matter experts, as well as bring expertise in algorithm and method development. This idea—de-risking computational

**Figure 9. The “Value Add” of the HPC4 Energy Innovation Initiative**



effort—must be exported to other government agencies, research laboratories, national laboratories and HPC centers to grow partnerships to capture the latent innovation potential unrealized in America.

The HPC4EI has limited time and resources and uses a competitive application process to identify the highest impact work. Companies apply to the program through a solicitation process which determines if a project matches subject matter expertise within the laboratory and has research or economic value. The laboratory matches projects to principal investigators within LLNL and a full proposal is reviewed. If the project passes review, the laboratory

and applicant organization sign partnership agreements and the work is officially funded. The DOE provides \$300K in funding to laboratories for each project, which must be met with at least a 20 percent in-kind contribution by industry to ensure they are supporting the work as well.

HPC4EI first launched as HPC4Energy, and its success has led it to create several iterations in other domains, including HPC4EI (replacing HPC4Energy) which is growing and supported by different offices within the DOE; HPC4Manufacturing, sponsored by the Office of Energy Efficiency and Renewable Energy, Advanced Manufacturing Office; HPC4Ma-

terials, sponsored by the Fossil Energy Office; and HPC4Mobility, sponsored by the Office of Energy Efficiency and Renewable Energy, Vehicle Technologies Office. The DOE is growing funding for the program through these new HPC4EI subprograms and is growing project funding for LLNL and eight other laboratories.

Lessons learned from HPC4EI:

- The program is particularly valuable for identifying laboratory SMEs for industry;
- The small projects are good for making a go/no go decision on further work;
- Growth in the existing program—or scaling to other agencies—would require a better articulation of how to engage industry; a better explanation to industry of the computation resources at hand; and
- Mission alignment between industry and sponsor organizations is not always 100 percent, which limits funding.

**Next Steps:** The HPC4EI has proven to be an effective PPP model that could perhaps be scaled—not just engaging additional labs and energy-focused companies, but also across other agencies and mission space with computing needs/gaps.

And the existing program must be positioned at a cross-cutting level to pull in the greatest resources at any national laboratory or high performance computing center that might participate in a new PPP. In addition, it should receive new, non-programmatic funding, which will be cost-shared at the programmatic level. This allows for available funding at the laboratory without cutting into existing programs, and cost-share ensures projects are of value to the nation, which would alleviate the need for exact industry-programmatic mission alignment. It would also help diversify the portfolio of work to several programmatic areas. Finally, it should include funding for university collaborations to ensure the next generation of workers are engaged in these collaborations and building skills valuable to industry.

## MODEL: HPC4EI

Steps/Responsibility	Public	Private
Companies apply to the program through a solicitation process		✓
The laboratory matches projects to principal investigators within LLNL and a full proposal is reviewed	✓	
Sign partnerships agreements	✓	✓
Conduct research	✓	✓

## MODEL: Growing Familiarity with Advanced Computing

**Identified Problem:** Relatively poor general awareness within industry—especially in SMEs—of the power of HPC, and modeling and simulation undermines potential U.S. competitiveness.

**PPP Solution:** Overcome education, training and cultural barriers to greater adoption and support for advanced computing across the U.S. economy.

Advanced computing represents an important research, modeling, simulation and analysis tool in America's arsenal of tools for innovation, but its potential economic impact is blunted by its underuse stemming from its low application among small and medium-sized companies. America's future competitiveness relies on effective use of its resources, which necessitates elevating U.S. leadership in advanced computing to a national priority among the general population.

More generalized use of advanced computing across industry and all aspects of life requires a population with a more robust base in science, technology, engineering and mathematics. Yet, the United States is starting from a position of weakness. According to the 2018 Program for International Student Assessment (PISA), the United States continues to fall behind other nations in reading, math and science, and has a growing gap between high- and low-performing students, suggesting a high discrepancy between education quality and student aptitudes

### Case Study

Proctor & Gamble Partnership with University of Cincinnati to develop High Performance Computing skills in future workforce

- P&G works with students on HPC machines
- Exposes students to new resources and they get to work on real problems, motivating their work on HPC
- University of Cincinnati serves as a pipeline for students to join P&G, which benefits the company because they know students graduate with the necessary skills to succeed.

[https://www.aplu.org/projects-and-initiatives/economic-development-and-community-engagement/innovation-and-economic-prosperity-universities-designation-and-awards-program/IEP\\_Library/university-of-cincinnati-procter-gamble-university-of-cincinnati-simulation-center/file](https://www.aplu.org/projects-and-initiatives/economic-development-and-community-engagement/innovation-and-economic-prosperity-universities-designation-and-awards-program/IEP_Library/university-of-cincinnati-procter-gamble-university-of-cincinnati-simulation-center/file).

[https://www.eurekaalert.org/pub\\_releases/2008-12/uoc-uap121108.php](https://www.eurekaalert.org/pub_releases/2008-12/uoc-uap121108.php).

### Council on Competitiveness Efforts to Democratize HPC as a Tool of Innovation

The Council has been working to heighten use of HPC, and modeling and simulation since 2004. In particular, the 2015 report *Modeling, Simulation and Analysis, and High Performance Computing: Force Multiplier for American Innovation* built on the years of Council activities to make the business case for HPC and was a major contributor to the creation of the National Digital Engineering and Manufacturing Consortium (NDEMC)—an industry-led, public-private supercomputing partnership to support a robust, agile and globally competitive U.S. supply chain—founded in 2011 with the Obama Administration.

around the country.<sup>11</sup> Of the 79 nations participating in the 2018 assessment, the United States ranked 13th in reading, 18th in science and 37th in math. (Figure 10).

Looking across similar assessments dating back more than 15 years, the trend has been that students in other nations have tested above the United States for years (Figures 11 and 12). More worrying, however, is that after a short rise in U.S. math scores between 2006 and 2009, U.S. scores have dropped steadily such that the recent 2018 assessment found average scores below the first year of published results in 2003.

America's education system is not doing as good a job as other nation's to create an innovation-capable workforce, undermining long-term U.S. competitiveness.

Exposure is also an issue for advanced computing. Americans currently do not have a broad awareness of advanced computing/HPC resources, or are not sure of how to interact with one even if they have an understanding of how and when the resource should be applied to their work. Few advanced computing resources are available for potential users to explore, and students not exposed to advanced computing early in their academic career are not adequately trained on it as a tool to enhance research and product development lifecycles when they enter the job market.

Certain institutions—such as large corporations, national laboratories, research universities and government facilities—may have advanced computing resources at their disposal, but advanced computing does not always present a clear return on investment. Often it is seen as a cost center rather than an investment.<sup>12</sup> Education curricula need much earlier to integrate concepts related to computing—raising the profile of the power of computing, modeling and simulation to solve concrete problems. This would also serve to help demystify computing, while also changing the perception of computing as a “cost” to an “investment.”

11 [https://www.washingtonpost.com/local/education/us-students-continue-to-lag-behind-peers-in-east-asia-and-europe-in-reading-math-and-science-exams-show/2019/12/02/e9e3b37c-153d-11ea-9110-3b34ce1d92b1\\_story.html?arc404=true](https://www.washingtonpost.com/local/education/us-students-continue-to-lag-behind-peers-in-east-asia-and-europe-in-reading-math-and-science-exams-show/2019/12/02/e9e3b37c-153d-11ea-9110-3b34ce1d92b1_story.html?arc404=true).

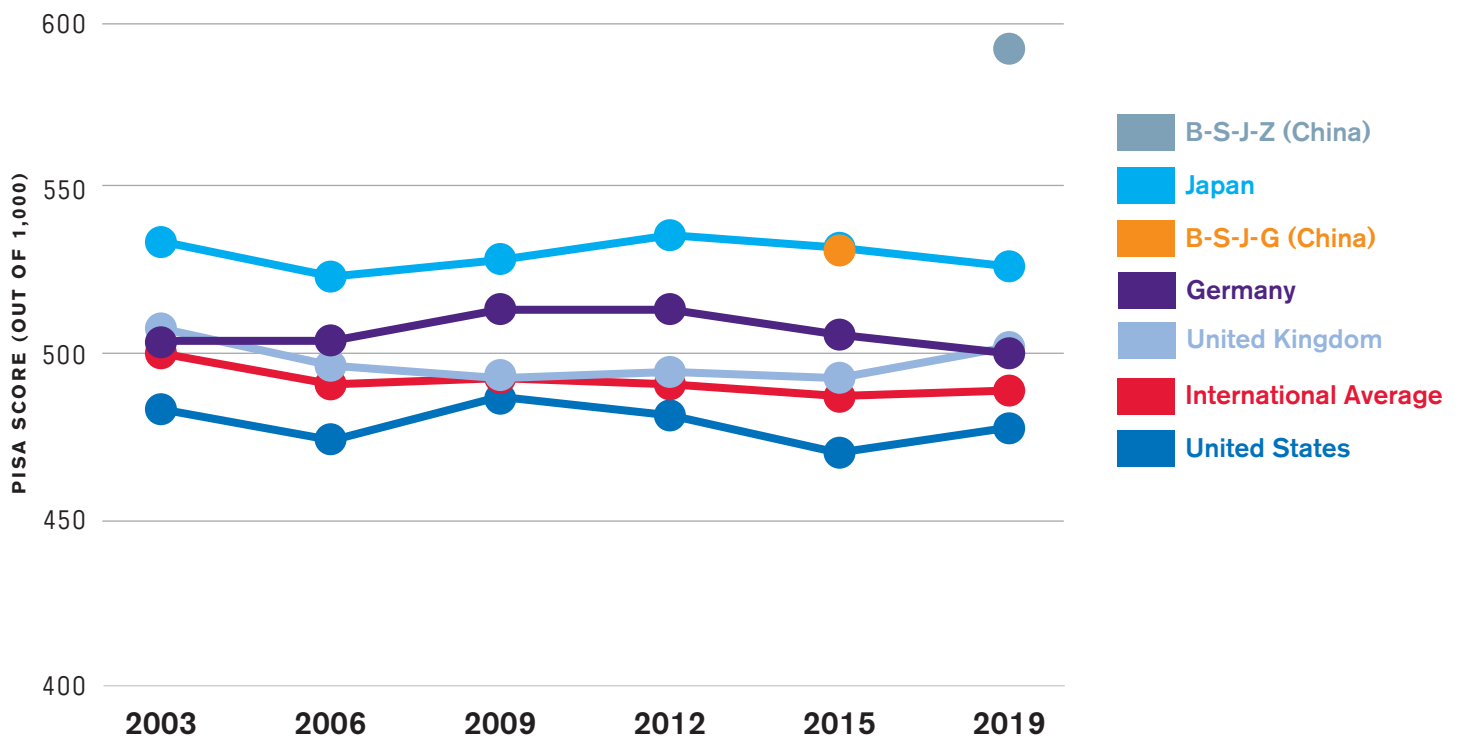
12 <https://www.compete.org/storage/images/uploads/File/PDF%20Files/2004%20HPC%2004%20Users%20Conference%20Final.pdf>.

Figure 10. 2018 PISA Rankings (Top 38)

Reading	Science	Mathematics
China (four provinces)	China (four provinces)	China (four provinces)
Singapore	Singapore	Singapore
Macau (China)	Macau (China)	Macau (China)
Hong Kong (China)	Estonia	Hong Kong (China)
Estonia	Japan	Taiwan
Canada (tie)	Finland	Japan
Finland (tie)	South Korea	South Korea
Ireland	Canada	Estonia
South Korea	Hong Kong (China)	Netherlands
Poland	Taiwan	Poland
Sweden (tie)	Poland	Switzerland
New Zealand (tie)	New Zealand	Canada
United States	Slovenia	Denmark (tie)
United Kingdom (tie)	United Kingdom	Slovenia (tie)
Japan (tie)	Australia (tie)	Belgium
Australia (tie)	Germany (tie)	Finland
Taiwan (tie)	Netherlands (tie)	Sweden (tie)
Denmark	United States	United Kingdom (tie)
Norway	Sweden (tie)	Norway
Germany	Belgium (tie)	Ireland (tie)
Slovenia	Czech Republic	Germany (tie)
Belgium (tie)	Ireland	Czech Republic (tie)
France (tie)	Switzerland	Austria (tie)
Portugal	Denmark (tie)	Latvia
Czech Republic	France (tie)	France (tie)
Netherlands	Portugal	Iceland (tie)
Austria (tie)	Norway (tie)	New Zealand
Switzerland (tie)	Austria (tie)	Portugal
Latvia (tie)	Latvia	Australia
Croatia (tie)	Spain	Russia
Russia (tie)	Lithuania	Italy
Italy (tie)	Hungary	Slovak Republic
Hungary (tie)	Russia	Luxembourg
Lithuania (tie)	Luxembourg	Hungary (tie)
Iceland (tie)	Iceland	Lithuania (tie)
Belarus (tie)	Croatia	Spain (tie)
Israel (tie)	Belarus	United States
Luxembourg (tie)	Ukraine	Belarus (tie)

**Figure 11. U.S. Scores on the PISA Math Assessment are Below the International Average and are Lower Now than when Assessments Began**

Source: Program for International Student Assessment (PISA)



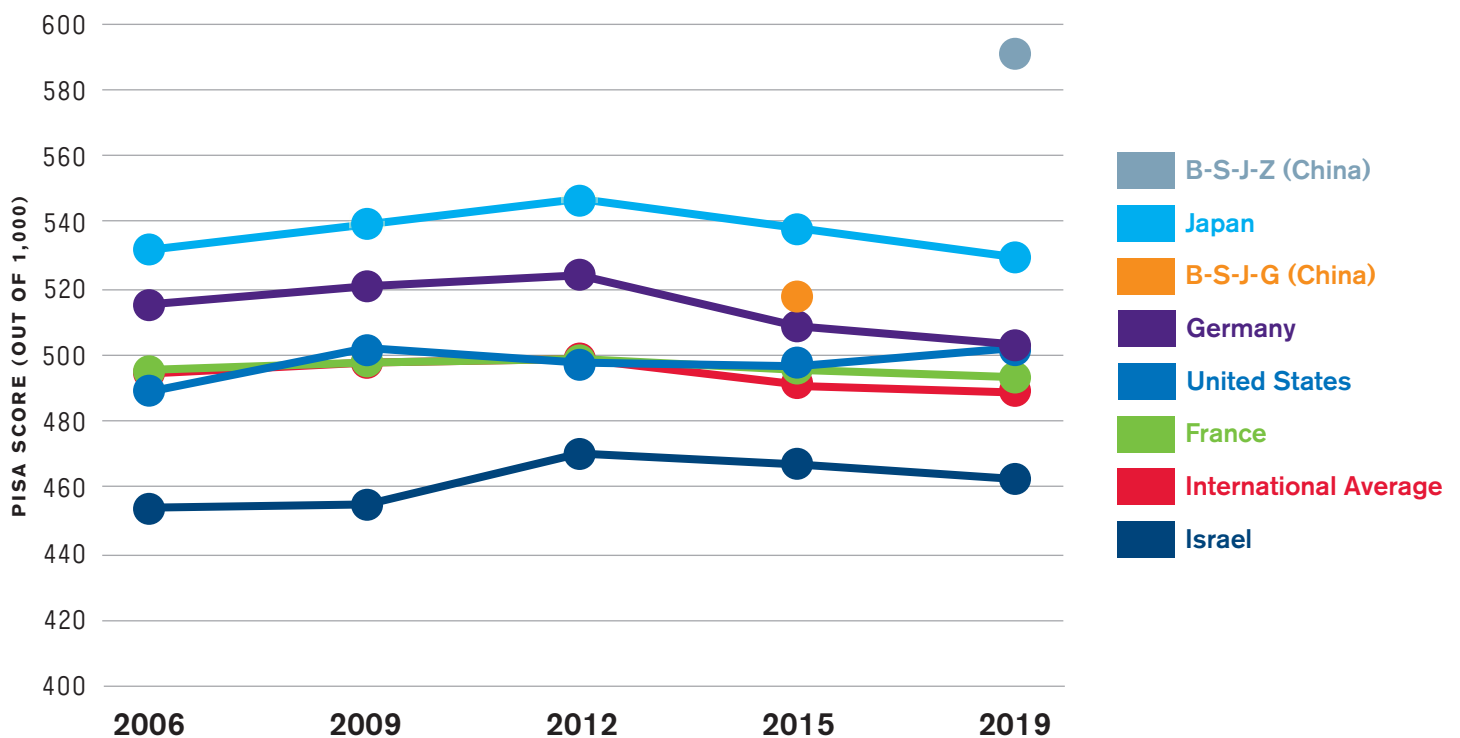
A final component to support greater adoption is to make advanced computing interfaces more approachable. Building a set of standardized, user-friendly, domain-specific interfaces would lower the barrier to many users interested in applying advanced computing to their problem, but who do not have the requisite technical computing capacity.

**Next Steps:** Further refinement of this model would require deep engagement with academic and advanced computing users to identify the skills most important to instill in young students and the age

at which it is appropriate to begin introducing these skills into a curriculum—either at a state-by-state or federal level. It would also require efforts from both industry and the public sector to identify domains where HPC application would generate the most economic benefit and work to fast track advanced computing interfaces in this space as a means to speed adoption.

**Figure 12. U.S. Scores on the PISA Science Assessment Continue to be in the Middle of the Pack**

Source: Program for International Student Assessment (PISA)

**MODEL: Growing Familiarity to Advanced Computing**

Steps/Responsibility	Public	Private
Identify economic sectors of greatest importance to future competitiveness	✓	
Identify necessary skills to succeed in future economies		✓
Build skills and expose to advanced computing into public academic curricula and educational standards	✓	
Customize and simplify interfaces for advanced computing in these spaces for quick adoption by industry	✓	✓

# Future Areas of Research and Analysis

The continued and rapid transformation of technology will necessarily change the tools of innovation, extent and nature of involvement of stakeholders in PPPs, and incentives for developing and deploying new technologies. The PPP models proposed in this report relate to a moment in time where incentives align in such a way that these models can succeed.

However, as the public and private sectors evolve over time in response to new technologies, business models and incentive structures, the Council (and funders of advanced computing capabilities) must constantly re-engage stakeholders to understand how their motivations have shifted, driving their interests and investment decisions in new directions. For example, a key model explored ways to expose more of America's current and future innovators to advanced computing as a tool to enhance their own efforts. The growing democratization of tools for innovation may obviate this PPP in several years, but the United States must not let future obsolescence deter current action to optimize the current innovation ecosystem.

Deeper understanding of stakeholder motivations will improve future models for partnership, and defining measurable traits of PPPs will improve the quality of assessments examining the effectiveness of such partnerships in the future. To this end, potential future pathways for this research may follow several distinct but related avenues:

1. Engage more sector-specific computing users to understand unique challenges of a given domain. This may enhance future branches of a growing HPC4EI partnership around the nation.
2. Continually survey stakeholders in efficient PPPs as political and economic environments change to refine key metrics and identifiers contributing to success. Understanding why PPPs are successful will also help stakeholders identify when market conditions support the creation of a new PPP.

The Council looks forward to exploring these proposed pathways to further enhance the effectiveness of PPPs and catalyzing new opportunities to sustain and continue to develop U.S. competitiveness.

# About the Council on Competitiveness

For more than three decades, the Council on Competitiveness (Council) has championed a competitiveness agenda for the United States to attract investment and talent and spur the commercialization of new ideas.

While the players may have changed since its founding in 1986, the mission remains as vital as ever—to enhance U.S. productivity and raise the standard of living for all Americans.

The members of the Council—CEOs, university presidents, labor leaders and national laboratory directors—represent a powerful, nonpartisan voice that sets aside politics and seeks results. By providing real-world perspective to Washington policymakers, the Council's private sector network makes an impact on decision-making across a broad spectrum of issues—from the cutting edge of science and technology, to the democratization of innovation, to the shift from energy weakness to strength that supports the growing renaissance in U.S. manufacturing.

The Council's leadership group firmly believes that with the right policies, the strengths and potential of the U.S. economy far outweigh the current challenges the nation faces on the path to higher growth and greater opportunity for all Americans.

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