



Compete.

Council on
Competitiveness

BUILD for Advanced Computing

3

May 14, 2019

Co-hosted by the University
of Texas System
Austin, TX

Post Report

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Table of Contents

| | |
|--|----|
| Participants | 2 |
| Agenda | 4 |
| What is BUILD? | 8 |
| What is Advanced Computing? | 9 |
| The National Strategic Computing Initiative—and its Key Goals | 11 |
| Background on Public-Private Partnerships | 12 |
| BUILD 1 and 2 Summaries | 16 |
| Findings from the BUILD 1—Pittsburgh, PA | 18 |
| Executive Summary | 19 |
| Framing Thoughts from BUILD Leaders | 21 |
| Proposed PPP Models | 21 |
| Perspectives on PPP Concept 1: Accelerators for American Computing | 22 |
| Perspectives on PPP Concept 2: Leadership in Microelectronics and Advanced Computing | 24 |
| Advanced Computing Sector Deep Dives and Other PPP Opportunities | 27 |
| Closing Comments and the Path Forward | 33 |
| About the Council on Competitiveness | 35 |
| Council on Competitiveness Members, Fellows and Staff | 36 |

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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.

What is BUILD?

BUILD for Advanced Computing is a national, public-private effort led by the [Council on Competitiveness](#) (Council) and supported by the National Science Foundation (NSF) to improve and expand public-private collaboration in ways that support the efforts of the National Strategic Computing Initiative (NSCI) and its Joint Program Office (JPO) to spur advanced computing technologies underpinning federal missions in scientific discovery, national security, and economic competitiveness. (We define “advanced computing” broadly to encompass, for example, supercomputing, artificial intelligence (AI), machine learning, quantum computing, etc.)

The public and private sectors must collaborate (more productively and at greater scale) if the United States is to maintain a modern, competitive advanced computing ecosystem that is able to push forward this objective. Only together can public and private actors develop and deploy the technological capability, computational foundations and workforce capacity needed to preserve American leadership in advanced computing.

The Council regularly convenes industry, academia and the national laboratories to understand emerging technology issues and recommend solutions that would advance U.S. competitive interests, leveraging its partnerships with the Council’s distinctive network of members and affiliates to offer distinctive insights into the present state of knowledge in technology partnerships. The Council has a deep commitment to understanding the roles advanced computing play in driving U.S. competitiveness, with long-standing and ongoing initiatives to promote HPC as a foundational technology and business asset for improving U.S. productivity and prosperity.

BUILD for Advanced Computing is bringing together a cross-section of national leaders to address a rapidly shifting national and global advanced computing landscape; and uncover the actions that can be taken to enable America to bolster dramatically the value of its advanced computing R&D and partnerships over the next 20, 30, 40 years and beyond.

The overarching goals of the effort are to:

- State and define key barriers, challenges, and problems in U.S. advanced computing R&D.
- Dive deeply into these problems and generate possible policies, solutions, and models—including tangible and implementable opportunities—where the U.S. public and private sectors can work together to prioritize and solve these problems.
- Evaluate and catalyze policy solutions—including at least 5 potential models for scalable, public-private partnership (PPP) pilot projects/concepts generated by the proposed effort—to ensure the benefits of the R&D supported by the NSCI will have an enduring positive effect on U.S. industry and academia.
- Generate a final, detailed proposal of some PPPs based on the policies and models evaluated that can be carried out by the JPO and/or the Council to increase the competitiveness of the U.S. advanced computing ecosystem.

In partnership with our distinctive network of members and affiliates in the advanced computing space, the Council is hosting this progressive dialogue series across the country—exploring different geographies, local innovation assets, distinctive challenges, and scalable opportunities.

What is Advanced Computing?

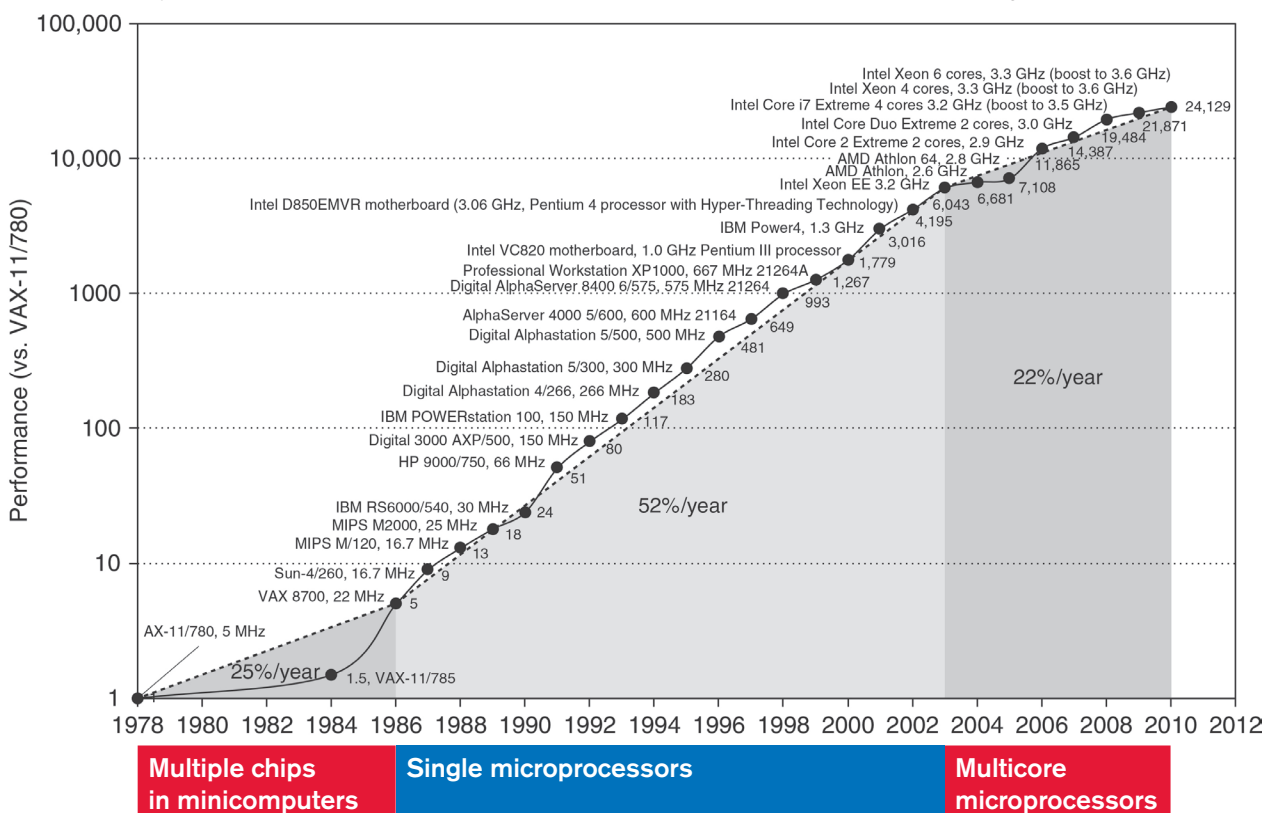
Advanced computing is the systematic use and development of domestic high-end computer hardware, operating and applications software, data management and analytics, visualization tools, and necessary infrastructure, talent and knowledge to exploit these capabilities to solve science, engineering, industrial and commercial, and energy and national security challenges. It includes technologies such as HPC, AI, and the Internet of Things (IoT). Most importantly, advanced computing technologies enable cutting-edge science, innovation and engineering.

Advanced computing is a foundational technology that has an enormous and growing impact on America's science, security and economic interests—all of which are interrelated. However, advanced computing in the United States is confronted by two significant problems.

First, the United States, a long-time leader in this realm, faces increased global competition in advanced computing, as resources to develop the many technologies represented in advanced computing are more readily accessible, tapping into latent innovation capacity in countries around the world.

Computing Performance Improvement Slowing (SPECint Benchmark)

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



Without aggressive support from the U.S. public and private sectors, the United States is at risk of ceding its leadership role and falling behind global competitors in the development of advanced computing resources.

Second, Moore's Law—an observation from cofounder 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. Moore's Law is reaching fundamental limits—placing demands on the microelectronics industry to find, develop and deploy at scale new methodologies for research and new manufacturing processes to move beyond the existing computing industry paradigm.

Overcoming these challenges will require cooperation between the public and private sectors, bringing together the vast resources, market intelligence, and industry-building capabilities found in different segments of the economy.

The National Strategic Computing Initiative—and its Key Goals

The National Strategic Computing Initiative (NSCI) is a whole-of-nation effort to accelerate scientific discovery and economic competitiveness by maximizing the benefits of HPC research, development, and deployment.

On July 29, 2015, the NSCI was established with the NSF as one of three lead agencies together with the Department of Defense and the Department of Energy. The NSCI calls on the NSF to play a leadership role in scientific discovery advances, the broader HPC ecosystem for scientific discovery and workforce development. A NSCI [Strategic Plan](#) was made public in July 2016.

The NSCI aims to address five strategic objectives:

1. Accelerate delivery of a capable exascale computing system;
2. Increase coherence between technology for modeling/simulation and data analytics;
3. Establish a viable path forward in the “post-Moore’s Law” era;
4. Increase the capacity and capability of an enduring national HPC ecosystem; and
5. Develop U.S. government, industry, and academic collaborations to share the benefits.

The NSF is primarily focusing on objectives two through four and will also contribute to basic research towards extreme-scale computing (objective one) and strengthening public-private collaborations through existing programs (objective five).

NSF’s participation in the BUILD Series provided participants with important context as they discuss the various PPP models under consideration. In particular, this conversation highlighted the complementarity of HPC, national security, science and engineering capabilities and industrial competitiveness.

During this session on the NSCI’s background and purposes, dialogue participants raised several critical points that resurfaced throughout the day, including the importance of revitalized domestic manufacturing to support emerging industries such as quantum computing and the pressing need to recruit and retain top-tier talent as part of a broader push to revamp the entire ecosystem of education.

Background on Public-Private Partnerships

Collaboration is a critical factor for driving innovation in the economy. 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 to be directed into sustainable solutions for public and private needs.

Through partnerships, organizations not only share resources, they also share potential risks and rewards from the development of a new product, process or technology, and benefit from shared accountability. The best elements and comparative advantages of both sides are brought to the table. Industry partners can enable efficiency in the development of the products while governmental bodies can contribute standards of knowledge and resources to complete the project, ultimately for use in the public domain. There is a significantly higher chance that projects operating under a PPP model are more likely to meet cost and schedule objectives.¹

The Council characterizes PPPs across four models rather than a strict categorization and suggests PPPs should be characterized by the predominant focus of each PPP.² The Council notes that while

one model may predominantly distinguish a PPP, it may also have characteristics that 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 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. Laboratory 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.

1 "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>.

2 *The Power of Partnerships*. Council on Competitiveness. 2013. https://www.compete.org/storage/images/uploads/File/PDF_percent20Files/AEMC_Power_of_Partnerships_FINAL.pdf.

Agreements for Commercializing Technology (ACTs)

Source: Council on Competitiveness

ACTs offer more flexibility in negotiating intellectual property rights for technologies created at participating national laboratories. More flexible terms are also available under ACTs on issues like payment arrangements, project structures, and indemnification. ACTs seek to ease the creation of multi-party R&D partnerships so companies, universities and other entities can come together with a laboratory to address complex technological challenges of mutual interest.

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 from across supply chains.

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 these PPPs 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 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 the government to operate them or by nonprofits established by members participating in the PPP. The leadership of the PPPs in the Council's [The 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). This theme, for instance, substantially enhances the productivity of a growing community of scholars, researchers

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)

and engineers through access to advanced digital services that support open research through NSF funding.³

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 five 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 research and development (R&D) with industry or fee-for-service contracts for industry researchers to use laboratory infrastructure.

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

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 complicated, even with partners.

The presence of a clear legal framework coupled with strategy meetings to clarify the role of each partner can help mitigate issues that typically surface in PPPs. 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 through 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.

BUILD 1 and 2 Summaries

BUILD 1 Summary

BUILD 1 was grounded in a historical overview of developments in advanced computing, while looking ahead at potentialities and possibilities in an era of disruptive change. Ongoing development around the end of Moore's Law, driven by approaching the functional limits of miniaturization in the coming decade regarding number and size of transistors per chip, is transforming America's technological landscape.

Advanced computing has a tremendous potential to positively impact economic growth and productivity—a key driver of higher living standards. In fact, since 1974, one-third of annual labor productivity growth has come from information technology (IT). Some suggest the end of Dennard scaling in 2004 might be related to a same-period blip in productivity growth, which historically has grown in the past 30 years, but has tapered off significantly.

Computers are a general-purpose technology and abide by the following standard cycle: the technology advances, more users adopt the technology, innovation is financed, and repeat. However, while this cycle has been ongoing for many decades in computing, disruption is now occurring at every stage. There has been a slowdown in technological advances, fewer users are adopting new technologies and computing is increasingly more difficult to finance. This has led to fragmentation and a breaking down of the computing ecosystem.

For example, performance improvement of microprocessors has slowed down. Additionally, the average replacement age for a computer has risen from four years to five-six years. People also are moving away from generalized CPUs (central processing units) to specialized units, such as GPUs (graphics processing unit) and TPUs (tensor processing units). Chip manufacturing costs are also rising. For instance, fabrication costs are rising at around 13 percent per year. This is compounded by market consolidation, leading to fewer new innovative players in the computing space. These challenges require both creators and users of computing technology to restructure the way they think about advanced computing.

One potential resolution is to deploy increasingly specialized chips, which would involve significant speed-up from moving to, for example, an NVIDIA GPU, which are especially relevant for machine deep learning. Specialization is more attractive if CPUs are improving slowly. Specialization would accelerate existing trends, leading to a fracturing of computing into fields such as universal/general computing, bitcoin, deep learning and others. It would also create clear winners and losers in the computing ecosystem, rather than ensuring collective improvement, as has been true in the past.

Along with specialization, another potential pathway to success is to move collectively to the next-generation computing technologies, such as quantum, carbon nanotubes, 3D chips and superconductors. This would preserve relative uniformity without increasing the possibility of winners and losers.

However, if specialization and next-generation technologies are indeed the future, current levels of investment in R&D will likely prove insufficient. Additionally, the benefit of specialization is largely one-time, meaning that increased adoption of specialized chips could hurt everyone in the computing space in the long run. Perhaps the only way to solve long-term problems in computing is to invest significantly more in these next/emerging technologies. At the same time, better application and utilization of existing frameworks and technologies could be sufficient if done effectively.

BUILD 2 Summary

On March 11, 2019, the Council, the University of California, San Diego and the San Diego Super-computer Center co-hosted the second Building University-Industry-Laboratory Dialogue (BUILD) for Advanced Computing in San Diego, CA.

More than 40 participants from industry, academia, national laboratories and government attended the event, bringing together advanced computing and PPP subject-matter experts to explore new models of engagement.

Dialogue conversation raised the following top-level takeaways as critical elements when considering building and identifying desired outcomes in new-to-world models for PPPs:

- U.S. competitiveness in emerging fields, such as quantum computing, will require a domestic manufacturing sector capable of meeting the industrial and technical needs of future technologies. Securing U.S. positioning quickly is critical given the speed of global innovation and China's emerging strength in the HPC marketplace.

- The U.S. microelectronics and computing industries face the possibility of revolutions in how computing is researched, scaled and applied, as well as monumental global shifts that undermine the U.S. position in the global economy in these fields.
- The United States needs to re-evaluate how the public interacts with science and technology, beginning by delivering essential technical knowledge outside the traditional educational pipeline early in children's academic careers.
- The United States has a significant advanced computing skills gap that will weaken its ability to compete globally unless this underlying issue in the educational system is addressed.
- The promise of advanced computing will never be realized without significant efforts on behalf of both the public and private sectors to overcome looming technical challenges.

The second dialogue brought a refined vision for a PPP model that surfaced during the first dialogue—reframed as “Accelerators for American Computing” that aims to dive deeper into a means of creating distinct streams for processing components specialized by task—and an entirely new PPP model seeking to develop a technological underpinning for general computing power.

Findings from BUILD 3— Austin, TX

Executive Summary



Participants of BUILD 3 in Austin, TX.

On May 14, 2019, the Council and the University of Texas System co-hosted the third and final Building University-Industry-Laboratory Dialogue (BUILD) for Advanced Computing in Austin, TX.

BUILD for Advanced Computing is a three-part progressive dialogue series with the goal of delivering to the National Science Foundation (NSF) several concrete new-to-the-world PPPs models relating to advanced computing to help support the National Strategic Computing Initiative (NSCI) being overseen by the Joint Program Office for Strategic Computing (JPO-SC).

This third dialogue built on the work of the first two dialogues, respectively held at the University of Pittsburgh in Pittsburgh, PA, in November 2018, and the University of California San Diego and San

Diego Supercomputer Center in San Diego, CA, in March 2019. These previous dialogues surfaced two new-to-the-world PPP models, identifying stakeholders and markets that would benefit from the inherent strengths of public and private actors, and that were poised for growth. Each delved into the local innovation ecosystems and top-level partnership takeaways, exploring health and biotechnology in Pittsburgh, exploring health and wellness, as well as greater prediction and mitigation tools for natural disasters in San Diego.

More than 40 participants from industry, academia and government attended the third event, with diverse subject-matter expertise relating to advanced computing and PPPs.

Dialogue conversation raised the following top-level takeaways as critical elements when considering building and identifying desired outcomes in new-to-the-world models for PPPs:

- Efforts to continually improve efficiency and optimize existing resources will grow in importance as industry approaches the top of the S-curve of current computing technologies.
- The coming end of Moore's Law is having adverse effects on the semiconductor market and its participants, resulting in diminished domestic design and fabrication capabilities as reliance on foreign suppliers grows. This creates risks to national security as the nation's infrastructure, communications and defense technologies are constructed with elements increasingly made outside the United States.
- Tensions between national security and economic competitiveness vs. the need to engage global talent must be resolved to confront the technology challenges facing the nation.
- Work must begin on developing the next generation of computing, but stakeholders must decide on the longevity of bridge technologies (temporary vs. long-term solutions) if no estimated timeline or clear direction exists for the commercialization of next-gen computing technologies.

The day's conversations further refined a number of concepts and threads of discussions that will be thoughtfully considered moving forward as the Council prepares to submit its final report to the NSF outlining concrete suggestions for PPP models in the advanced computing space.

Framing Thoughts from BUILD Leaders

Dialogue leaders the Honorable Deborah L. Wince-Smith, President & CEO, Council on Competitiveness, and Mr. James B. Milliken, Chancellor, University of Texas System, opened conversation at the BUILD 3 by identifying several trends across the United States that collectively represent the foundation of America's global competitiveness. The United States has been a global leader for decades, but current leadership is under threat:

- Spend of GDP for R&D is falling relative to other industrialized nations;
- Dominance in supercomputing is diminished as other nations—primarily China—pour resources into building more high performance machines that rival U.S. resources;
- Access to quality education and the tools of innovation are still greatest in America, but a globally connected information ecosystem is quickly bringing down barriers; and
- While the United States continues to lead in entrepreneurial spirit and creativity globally, investment in small businesses and startups from international sources is growing.

Advanced computing is a key element of America's future competitiveness, representing a suite of converging technologies capable of dramatically expanding productivity potential. As echoed by opening comments from participants, advanced computing enables the collection, manipulation and analysis of data to improve efficiency, productivity and safety of work. Investment in advanced computing pays cross-sector dividends, but to fully capitalize on the potential of advanced computing resources, there must be collaboration and partnership between stakeholders to reach more corners of the economy.

“Our economic competitiveness depends on our ability to continue to lead in the world.”

Dr. James B. Milliken
Chancellor
The University of Texas System

Furthermore, collecting and analyzing information does not guarantee success. Data integrity and categorization must not be overlooked. Building and enhancing partnerships, leveraging the strengths of industry, academe, national laboratories and public resources is needed to sift out the useful from the useless data. Decisions made on bad information are potentially more harmful than not making any decisions at all.

For these reasons, the group was tasked by dialogue leaders to develop new-to-the-world models for PPPs, thinking critically how to engage a wide cross-section of advanced computing stakeholders to advance the mission of the National Strategic Computing Initiative.

Proposed PPP Models

Participants in this dialogue benefitted from the experience and thought leadership developed during BUILD 1 and 2, and were provided an opportunity to react to two PPP models surfaced in previous conversations. Applying new and different perspectives to these models strengthened the PPP proposals, heightening the potential for these models to succeed in the future.



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

Both models focused on the need to address the slowing of Moore's Law, though each model emphasizes a different path to maintain advanced computing's contributions to productivity growth. Driving these models is a recognition, echoed by all dialogue participants, that there exists a strong relationship between the digitalization of the economy and increasing demand for computational performance.

Since 1974, one third of labor productivity has come from information technology,⁴ but the looming end of Moore's Law signals an end for this type of growth and leads to a broader breakdown in technological development. If the end of Moore's Law means technology does not advance, users will be less inclined to replace technology, which in turn leads to fewer

resources to finance new innovations, and a breakdown in the cycle of technological development. To perpetuate this cycle, there must new innovation, a funding source and and users willing to validate the technology as first adopters. Where then, would the next tranche of computing power be sourced if there is no clear computing technology successor?

Perspectives on PPP Concept 1: Accelerators for American Computing

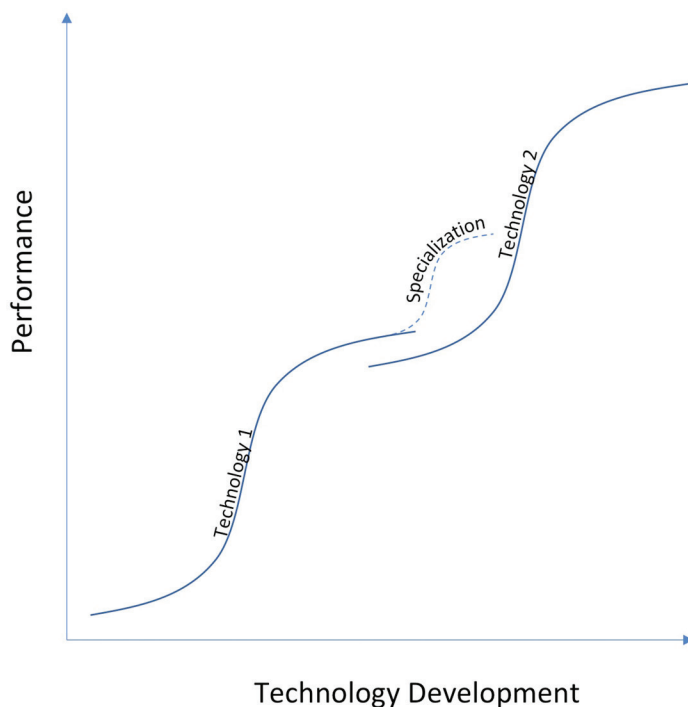
The slowdown in Moore's Law is seen in the concomitant slowdown in advanced computing technologies. This is due to the difficulty of continually increasing the density of transistors per chip combined with the rapidly increasing costs of manufacturing ever-shrinking semiconductors (Figure 1). There is no current market-viable technology representing a new tranch of performance and productivity enhancements to move advanced computing onto the next S-curve. However, slowing technology development in current microprocessor technologies has created a new opportunity to extend the S-curve through specialization, which can act as a bridge until a new computing technology is available that can provide the next productivity tranche.

Participants were presented with a new PPP model specifically calling for the development of 5-15 specialized processors targeted to improve American private sector performance and strategic governmental priorities.

4 Byrne, D., Oliner, S., Sichel, D., (2013) Is the Information Technology Revolution Over? *The Federal Reserve Board* <https://www.federalreserve.gov/pubs/feds/2013/201336/index.html#footnotes>.

S-curves Representing Technology Maturation Pathways

Source: Dr. Neil Thompson, MIT



This slowing down of computing performance improvement intersects with what was described as the cycle of a so-called general purpose technology, defined as such because of its flexibility to operate efficiently for many different purposes across the economy. Processors at the center of almost every digital technology have functioned as a general-purpose technology. As a general-purpose technology improves, more users adopt the technology, which in turn encourages additional financing of innovation leading to improved technology. This cycle continues

indefinitely until one element breaks the cycle, resulting in a cascading failure grinding the system to a halt. However, it was argued that every part of this cycle is currently broken, leading to market fragmentation.

The following metaphor concisely summarized the fragmentation: In the old model, a rising tide lifts all boats, while in the new model, there are fast and slow lanes. One cause of this divergence is the fact that many adopters of specialized chips only do so after the chip is on the market. Coordination problems and uncertain market size discourage investment.

Taken as a whole, this leads to market consolidation as smaller players are pushed out of the marketplace. With a fragmented computing landscape, specialization is more attractive now that CPUs are improving slowly.

This PPP model, therefore, aims to operate in this new fragmented landscape. Underpinning the model's objectives is the idea that the long-term driver of economic prosperity is growth in productivity.

The public and private partners would have complementary roles to allow each side to specialize in areas of expertise. The role of the public partner agencies would be to analyze and prioritize the most important algorithms to industry and government, creating the necessary economic environment incentivizing private stakeholders to design, manufacture and program new processors.

Together, public and private partners in this model would propose and validate the portfolio. Private industry would then be free to explore alternative uses for processors to enhance existing and new activity elsewhere in the economy, leading to posi-

tive spill-overs from those who develop the chips to industries and sectors. The development of specialized chips via collaboration between industry partners, academia and government could benefit society at large.

Perspectives on PPP Concept 2: Leadership in Microelectronics and Advanced Computing

The second PPP model is focused around building domestic capacity for the design, manufacture and distribution of microelectronics and the building blocks of advanced computing within the United States.

The coming end of Moore's law is leading to the deterioration of the semiconductor market. Two decades ago, 25 different companies existed with leading-edge semiconductor fabrication facilities. Yet, as transistor size continued to diminish, the difficulty and complexity of designing and manufacturing semiconductors increased. As difficulty and complexity increased, the number of companies capable of competing fell 88 percent to three. Along the way, companies looking to compete merged and or acquired other firms, having the side effect of reducing collaboration between market participants as each looked to protect their own intellectual property. This trend represents a significant threat to productivity growth if the incentive to innovate through collaboration is removed from the marketplace.

“The United States freely licensed technologies. Would another country? We should not expect any generosity from a lethal economic competitor”

Mr. Dan Armbrust
Co-Founder and Director
Silicon Catalyst

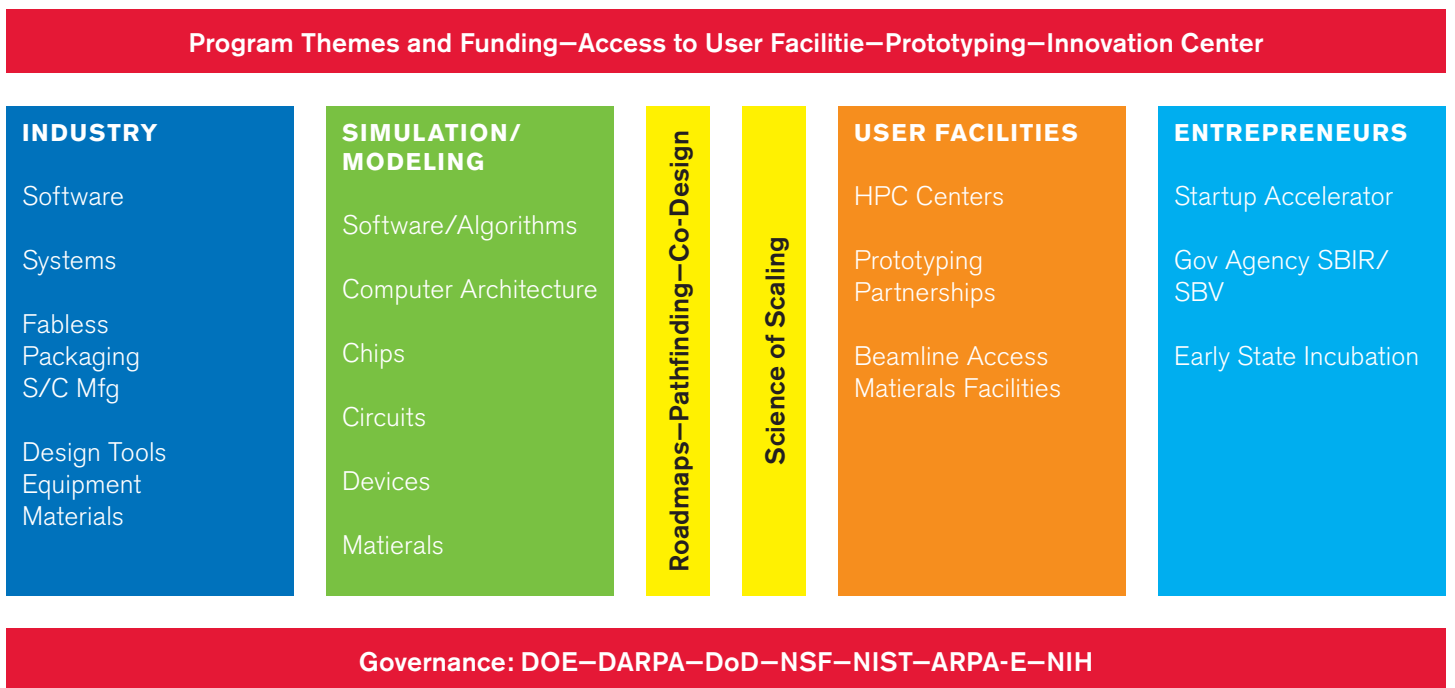
This new market alignment is also leading to the consolidation of seed money for new ventures in this space and creating incentives for large system companies able to invest in hardware powering their services to develop their their own semiconductors. National economies are feeling this pressure as well, especially in nations with significant electronics manufacturing capacity who are now incentivized to build home-grown capabilities. Currently, China consumes 60 percent of chips, yet produces less than 15 percent and is aiming to produce 40 percent by 2020 and 70 percent by 2025. China has acquired the technology and know-how to accomplish this through acquisition, joint venture, forcing companies operating in China to share intellectual property and well-documented IP theft. Beyond the United States not capturing value created from the design and manufacture of technology at the core of almost all future economic activity, it also creates a significant national security threat for trusted supply chains if the United States does not control technology inserted into American industries, research and physical infrastructure and defense.

Unfortunately, no single technology has emerged as a clear prioritized target for America's R&D, necessitating investment in many technology pathways, methods to accelerate/scale-up technology development and new financing models.

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 no investable mechanism to scale flower-

ing 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.

Public-Private Partnership Model Concept Proposed in "Leadership in Microelectronics and Advanced Computing"





BUILD 3 participants in conversation.

This will require a 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.

In response to this proposed PPP model, participants questioned the role of this PPP. Is developing the next tranche of productivity—finding the next S-curve, which can take a significant amount of time—the goal? Or rather, should the focus be on a bridge technology that will serve to continually enhance productivity linearly until a new S-curve-technology is commercialized? Participants noted that fabrication facilities shuttered in the United States would not easily re-open once a new technology emerges. Work must be undertaken to

keep industry and domestic resources in place and production-ready lest new facilities be needed in the future, carrying a larger price tag and time horizon.

Participants were also quick to recognize that investing in bridge technologies or the S-curve are not mutually exclusive. Augmenting current technologies and developing new-to-the-world technologies are complementary, rather than incompatible.

Reflecting on the need for a national commitment to this PPP model, participants surfaced existing players in this space not discussed. For example, the U.S. Trade Representative (USTR) and Department of Commerce (DoC) should be involved, as talks with China over trade are a large driver in the global technology supply chain. The USTR and DoC were involved with the development of SEMATECH when the United States faced a threat to its semiconductor design and fabrication dominance by Japan in the mid 1980s.

Participants questioned how to resolve the many issues necessary to see this PPP realized, namely revolving around bridging the divides in the nation over immigration to attract the best and brightest to compete globally in this space, as well as building consensus among citizens and policymakers across the political spectrum to build the national will to undertake such an initiative. Conversation did not resolve these issues, but participants agreed the need to scale a diverse array of technologies to maintain global technology leadership merited greater public discussion.

Advanced Computing Sector Deep Dives and Other PPP Opportunities

Army Profiles

Recognizing the potential strategic benefits of leveraging advanced computing resources to enhance national security and defense objectives, representatives of the DoD High Performance Computing Modernization Program (HPCMP) and Army Futures Command shared with participants efforts underway at the U.S. Department of Defense and Army to provide HPC capabilities and expertise to solve the nation's most critical DoD mission challenges.

The U.S. Army sees opportunities to leverage advanced computing resources to enhance national security across a number of military, engineering and supporting areas, and engages the development of new capabilities through the Engineer Research & Development Center (ERDC), which is part of the U.S. Army Corps of Engineers. The ERDC is supported by 2,500 employees, including more than 1,000 engineers and scientists, and works with other Information Technology Laboratory (ITL) programs and initiatives across the DoD to solve critical mission challenges.

The HPCMP—a DoD-wide program and national asset providing HPC capabilities, and one of the ITL's major programs—has been given four directions:

1. Significantly increase classified HPC capability for DoD mission priorities;
2. Deliver world-class computational power at the tactical edge;
3. Meet increased demand from PMs, PEOs, acquisition engineering and T&E communities; and
4. Grow HPC data analytics, artificial intelligence and machine learning capabilities.

These HPCMP directions shape DoD's science and technology priorities, such as hypersonics, directed energy, autonomy, microelectronics, space, cybersecurity, nuclear, quantum science and missile defense. Notably, these priorities are not an end unto themselves. They represent core competencies for the defense infrastructure of the United States, which enable new capabilities, either through concerted research in one area or through the confluence of multiple competencies.

The HPCMP and ERDC has found it can be more effective in its mission through partnerships with other federal agencies, industry and academia to apply new ideas and perspectives for enhanced problem-solving, bringing in new expertise and developing a pipeline for talent.

Starting a New Computing Ecosystem: A View from Industry

Conversations across the day varied in scope and vision, but participants agreed that computing is at a tipping point, sitting at the precipice of significant changes in the three foundations of computing:

- Energy, as prospects for increasing efficiency are dimmed with the end of Moore's law and extensively-scaled CMOS technology;
- Complexity, limited by bottlenecks of architecture schemes; and
- Error rates, which are approaching a theoretical minimum as errorless information transmission through optic cable reaches its theoretical maximum.

“Energy Efficiency is Computing Efficiency.”

Dr. Sasikanth Manipatruni
Chief Technology Officer
Kepler Computing

Moving from the technology of today to the technology of tomorrow will require advancing on each of these fronts—moving beyond CMOS, developing new AI architectures, and progressing from static to stochastic models.

There is precedent for leaps in computing technology. Every 20 years, a revolution is launched by a physics- and materials-driven 100x improvement in energy consumption, keeping in mind that energy efficiency equates to computing efficiency. Driving similar advancements across the computing ecosystem will require co-design among stakeholders to build the next computing revolution. However, starting a new computing ecosystem is expensive, demanding significant investment in researching, developing, scaling and deploying new technologies.

A primary hurdle is the expense of scaling a new platform. This hurdle can be overcome, and scaling significantly de-risked, through the creation of a co-design roadmap charting a path beyond CMOS. Important steps along the roadmap would include: expanding the budget and role of consortia to push for and invest in new technology; building infrastructure around a nationally-funded innovation hub

researching energy efficient electronics and next generation digital technologies; incentivizing investment through the private sector; and democratizing computing through open-source architecture and design tools with the additional benefit of creating new opportunities for entrepreneurship. The roadmap would stretch beyond the technology itself into workforce development—diversifying and expanding the recruitment of young talent to careers in the development of computing hardware—and recognize the national security implications of not seizing opportunities in this space. Successfully executing such a roadmap, rather than focusing on one of many potential computing technologies (such as quantum), would allow computing to branch out and potentially reach a higher tier of productivity. Co-designing this roadmap also enhances the potential for value generated by next generation computing to be more equitably captured and distributed.

The role of government in developing next generation computing cannot be understated, and agencies must make competitiveness a mission directive through which computing must be a critical and recognized element. Previous computing ecosystems thrived because of widespread investment and tying computing to mission-critical efforts. Building the connection between computing and competitiveness will also make it easier to build support for both new computing technologies and greater adoption of current computing technologies across federal agencies.

HPC4EI Program

The High Performance Computing for Energy Innovation (HPC4EI) Program is an effort funded by the U.S. Department of Energy and its national laboratory enterprise to engage industry to increase innovation and lower the risk of HPC adoption by



connecting best-in-class supercomputers, unique software and subject matter experts from national laboratories with members of industry that may benefit from such tools but do not have the resources or knowledge to apply HPC to their work. Augmenting the tools used in problem solving transitions testing and validation from Edisonian in nature—that is, innovation through trial and error—to predictive innovation using modeling and simulation to accelerate time to discovery.

In doing so, both industry and government benefit. Industry computational efforts are effectively de-risked; outputs are more advanced, with shorter time to market and enhanced quality; and manufacturing processes are optimized while using less material and energy. In turn, government benefits from less energy used in the economy and project investigators broaden their expertise, raising the likelihood of future projects benefitting from past experience. Broadening the base of experience is increasingly important as new technology development requires experienced talent across domains and subject matters, enabling converging technologies to grow to be more than the sum of their parts.

The success of the program has shown industry is interested in engaging in these types of partnerships, as well as that these partnerships provide valuable feedback to government to better identify and understand the needs of industry. To date, nearly 70 projects have been funded with more than 38 manufacturers in the United States, including everything from leading-edge aerospace companies and legacy industries to innovative small companies. Each company has to apply to the program using the same solicitation process, where a technical review committee will review a concept paper and proposal and match the particular challenge to a principal investigator in the national laboratory. Notably, the industry partner must agree to a 20 percent in-kind contribution cost share to the project to ensure their commitment to the research.

Currently, the HPC4EI umbrella covers: HPC4Manufacturing, sponsored by the DOE Energy Efficiency and Renewable Energy Office (EERE) and the DOE Advanced Manufacturing Office (AMO); HPC4Materials, sponsored by the DOE Office of Fossil Energy; and HPC4Mobility, sponsored by the DOE EERE Vehicle Technologies Office (VTO). And the size of

How the HPC4EI Program Works

Program Basics and Cost Sharing

The program pays labs up to \$300K (Demonstration-scale projects) to access HPC resources and expertise at laboratories; external partner provides at least 20 percent cost share (cash or in-kind).



Concept Submission

During a semiannual solicitation process, organizations may submit two-page concept papers describing ideas for projects of up to one year duration.



Lab Principal Investigator

If a concept is accepted, a lab principal investigator is assigned to help the organization develop a full proposal.



Selection Criteria

Projects must show:

- Advancing the state of the art
- Technical feasibility and strength of the team
- Industry impact
- Need for HPC systems



Signed Agreement

Following proposal approval, DOE provides the organization with a short-form cooperative R&D agreement (CRADA) to initiate the project.

HPC4EI continues to grow as the subprograms grow. Work thus far has also surfaced valuable lessons learned, such as identifying the value of these relatively small projects for making a go/no go decision on future work, the value of this program identifying laboratory subject matter experts for industry, and raising the need to better articulate a “next step” for industry with respect to computational resources.

This program holds significant potential to create value for the public and private sector, and to increase its chances for success at a larger scale, the program has been proposed to be positioned at a cross-cutting level to take advantage of the broad-

est number of resources. Similarly, it should receive non-programmatic funding with a cost-share at the programmatic level. Structuring the program in such a way allows for available funding without cutting into current programs and helps diversify the project portfolio to several programmatic areas. Program expansion may also benefit from additional funding for university collaborations to build greater exposure to industry problems, generate a talent pipeline, and engage subject matter experts within academia. With respect to industry engagement, HPC4EI leaders proposed increasing the cost-share to 25 percent, ensuring the project is of value to industry and by extension, the nation.



Mr. Jim Brinker, President, Intel Federal LLC; Dr. Jeff Nichols, Associate Laboratory Director for Computing & Computational Sciences, Oak Ridge National Laboratory; and Dr. Taylor Eighmy, President, The University of Texas at San Antonio.

Participants were concerned that expanding this program would lead to lowered HPC focus within industry, as industry may come to rely on the national laboratory system, while others noted many organizations lack the resources to build and operate HPC. Participants did come to agreement that intellectual property is a significant motivator for businesses and ownership of any IP—if created as part of the HPC4EI partnership—would need to be determined and agreed upon by all parties at the outset of any agreement.

The TACC

The Texas Advanced Computing Center (TACC) is a PPP between the University of Texas at Austin and the National Science Foundation to support 50,000 students, researchers and industry partners probing basic and applied research questions that cannot be addressed through other means.

“AI is great, but a panacea it is not.”

Dan Stanzione

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

When the TACC launched in June 2001, it was with a 50 gigaflop machine. Today, that machine represents 1/20,000th of current capacity as the TACC is home to Frontera, the fifth most powerful supercomputer in the world. As with the explosive growth in computing power, the TACC has had to grow quickly to accommodate the increasing number of researchers—notably, “as-a-service” users have grown significantly recently—and expanse of technology applications.

As a leadership-class computing facility, TACC is changing the way it works, looking to engage more with core university research facilities and programs. Part of this process will be developing science requirements through meetings with the scientific community to identify needs—if anything required is more than just a large computer. Inherent in collecting input from the scientific community will be standing up new prototypes and new vendors to see if and how they are used before investing significantly into these tools.

One such example experienced by TACC has been the importance and relevance of HPC beyond traditional computer modeling scenarios. An illustration shared with participants demonstrated how resources at TACC have been used to model the safety of a given area after a flood by incorporating the heights of electric outlets.

Ultimately, TACC sees future opportunities as endless, constrained only by the amount of time available to pursue opportunities. Artificial Intelligence, once scaled up, will only increase interest and demand for time with TACCs computing resources. However, software is the hardest part, and for this the slowing of Moore's law may be a good thing. The same chips will now be run for longer, rather than be put aside in favor of new, faster processors. This means software will have a greater opportunity to develop and exploit chips to their maximum—reminiscent of the day's first PPP conversation, "Accelerators for American Computing."

Closing Comments and the Path Forward

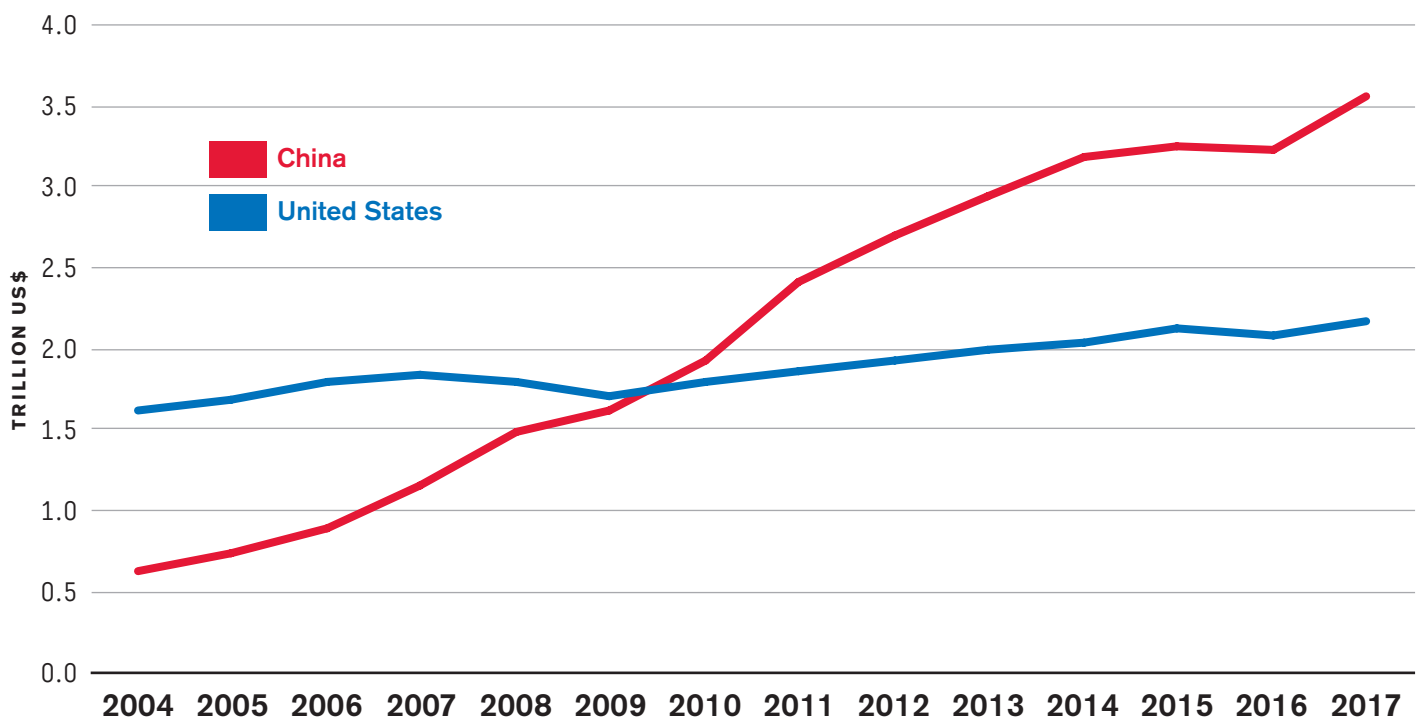
Dialogue leaders closed the conversation with a reflection on common themes from the day, expanding on the implications of building advanced computing capacity in the United States, as well as barriers to such capacity with domestic resources. Undeterred, participants emphasized the need to prioritize growth of advanced computing in the United States for reasons of National Security, ethical considerations and socializing AI in new formats to capitalize on new innovation opportunities.

Throughout the day, a clear tension emerged over the importance of national security—building a domestic manufacturing capacity, protected supply chain and workforce free from foreign influence

—and the need to engage and leverage global talent to confront technological challenges ahead. Participants noted a drain of talent and investment from the United States as other nations build their own advanced computing capacity, and as growing digitalization of daily life has lowered the need for co-location or proximity to resources. Over time, the increasing globalization of work has created a problem for trusted supply chains—especially for advanced computing resources working on national security or sensitive material. More specifically, China’s rapid growth, in part fueled by a surge in the value added from its manufacturing sector and domination in the global

Manufacturing, Value Added

Source: World Development Indicators



manufacturing of components used in advanced computing, introduces opportunities for unwelcome devices to enter the U.S. advanced computing space.

Participants thought back to previously successful PPP work on this issue, recalling the breath of federal government offices involved in the development of SEMATECH, such as the office of the U.S. Trade Representative and the U.S. Department of Commerce. Others in the conversation suggested the involvement of the federal government should be further expanded in this effort, including the Secretary of Defense as part of a national approach.

The rise of China as a growing leader in technology development created ethical concerns among participants. The responsibility of those developing new technology, and therefore first users, is to introduce ethical considerations for appropriate use. Recent new gene-editing technologies such as CRISPR raised similar concerns as different cultures projected different hesitations, or a sense of obligation, for applying the technology to different use-cases. First movers in the space have a large opportunity to control the narrative and direction of new technology, suggesting the United States should be in this position to set international standards for use by example.

Ethical concerns also reflected an awareness among participants that unethical applications of advanced computing may sow mistrust in advanced computing resources. Mistrust may slow adoption of new advanced computing technologies, limiting the potential to leverage those technologies for economic advantage and competitiveness. Participants noted Americans are already surrounded by advanced computing resources, and while they have grown to appreciate the value advanced comput-

ing has added, Americans are growing wary of new risks introduced. For example, 80 percent of people are satisfied with digital assistants from Amazon, Apple and Google (Alexa, Siri and Google Assistant, respectively) yet 41 percent have concerns about trust and privacy. Participants anticipate those concerns will grow as advanced computing resources require larger amounts of data or take greater responsibility for life and limb.

Echoing concerns raised during conversations over ethical concerns in the application of advanced computing, participants noted the extent to which privacy is protected or exploited differs across countries. New technological capabilities mean privacy is more exploitable than it has been in the past, and therefore risk assessments of technologies must change to react to and anticipate new capabilities.

Despite the above concerns, participants were enthusiastic about the potential of advanced computing to enhance the foundation of future economies, the importance of building hardware and software capabilities for advanced computing resources, and exploring opportunities to work with different stakeholders in the advanced computing community in the public and private sectors to materialize new partnerships.

The close of conversation in Austin, TX, represented the final in-person regional gathering for the BUILD Series, and the Council thanks all participants, especially hosts, for their time working to debate new-to-the-world PPP models to enhance the nation's innovation infrastructure. The Council will take conversations from the past three dialogues and create a final report, highlighting findings and identifying possible paths for future exploration.

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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