



Compete.

Council on
Competitiveness

BUILD for Advanced Computing

1

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Pittsburgh, PA

Post Report

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Agenda

MORNING

7:45 Registration and Light Breakfast

8:15 Welcome Remarks and Roundtable Introductions

Mr. Chad Evans
Executive Vice President
Council on Competitiveness

The Honorable Patrick D. Gallagher
Chancellor
University of Pittsburgh

Dr. Farnam Jahanian
President
Carnegie Mellon University

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

Possible questions to consider in framing the opening, one-minute statements:

- What is the most significant challenge to the research, development and deployment at scale of critical computing assets for 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 or organization?

8:45 Transition to Morning Sessions

8:50 What Are the National Strategic Computing Initiative and the BUILD for Advanced Computing Initiative

Mr. Mark Sims
National Strategic Computing Initiative (NSCI)
Joint Program Office for Strategic Computing (JPO-SC)

Ms. Thuc Hoang
Program Manager, Advanced Simulation and Computing National Nuclear Security Administration
U.S. Department of Energy

Mr. Chad Evans
Executive Vice President
Council on Competitiveness

9:20 The Future of Advanced Computing

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

Dr. Nicholas Nystrom
Interim Director
Pittsburgh Supercomputing Center

10:20 Coffee Break**10:30 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

10:35 PPP Deep Dive: Computing and Information Technology**Dr. Manish Parashar**

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

Dr. Rob Rutenbar

Senior Vice Chancellor for Research
University of Pittsburgh

Mr. Josh Simons

Chief Technologist for High Performance Computing
VMware, Inc.

11:30 PPP Deep Dive: Health and Wellness**Mr. Bill Gaussa**

Advanced Innovation Lead
Philips

Dr. Susan Gregurick

Director, Division of Biophysics, Biomedical
Technology and Computational Biosciences
National Institute of General Medical Services
National Institutes of Health

Dr. Shivdev Rao

Executive Vice President
UPMC Enterprises

AFTERNOON**12:30 Break and Move to Adjoining Room****12:30 Lunch and Cathedral of Learning Walking
Tour****1:45 PPP Deep Dive: Artificial Intelligence****Mr. Michael Garris**

Senior Scientist and
Founding Chair of the NIST AI Community of Interest
National Institute of Standards and Technology
(NIST)

Dr. Neil Thompson

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

2:45 Coffee Break

3:00 PPP Brainstorming Breakouts

Research from the Council on Competitiveness has identified a series of potential barriers to the development and scale-up of advanced computing technologies—enabling innovation, securing the talent pipeline, improving the business climate and addressing market risks.

In this session, participants will break out into smaller groups, address the following questions and suggest/develop specific recommendations that could—if implemented in the form of a public-private partnership—accelerate the scale up of advanced computing technologies.

Questions to consider:

- Do we have a shared, easily accessible, national innovation infrastructure and expertise on which companies and entrepreneurs can rely to develop and produce products more quickly and less expensively?
- Do we have the STEM and beyond talent necessary for advanced computing R&D and deployment?
- Do we have adequate investment in basic research and in supporting technologies that could lend advantage to advanced computing efforts (cutting-edge manufacturing; sensors; robotics; AI; etc.).

4:30 Brainstorm Reports

Each breakout group will present ideas for consideration by the group.

5:00 The Path Forward

Mr. Chad Evans

Executive Vice President
Council on Competitiveness

5:15 Closing Reception

6:15 Reception Ends

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?

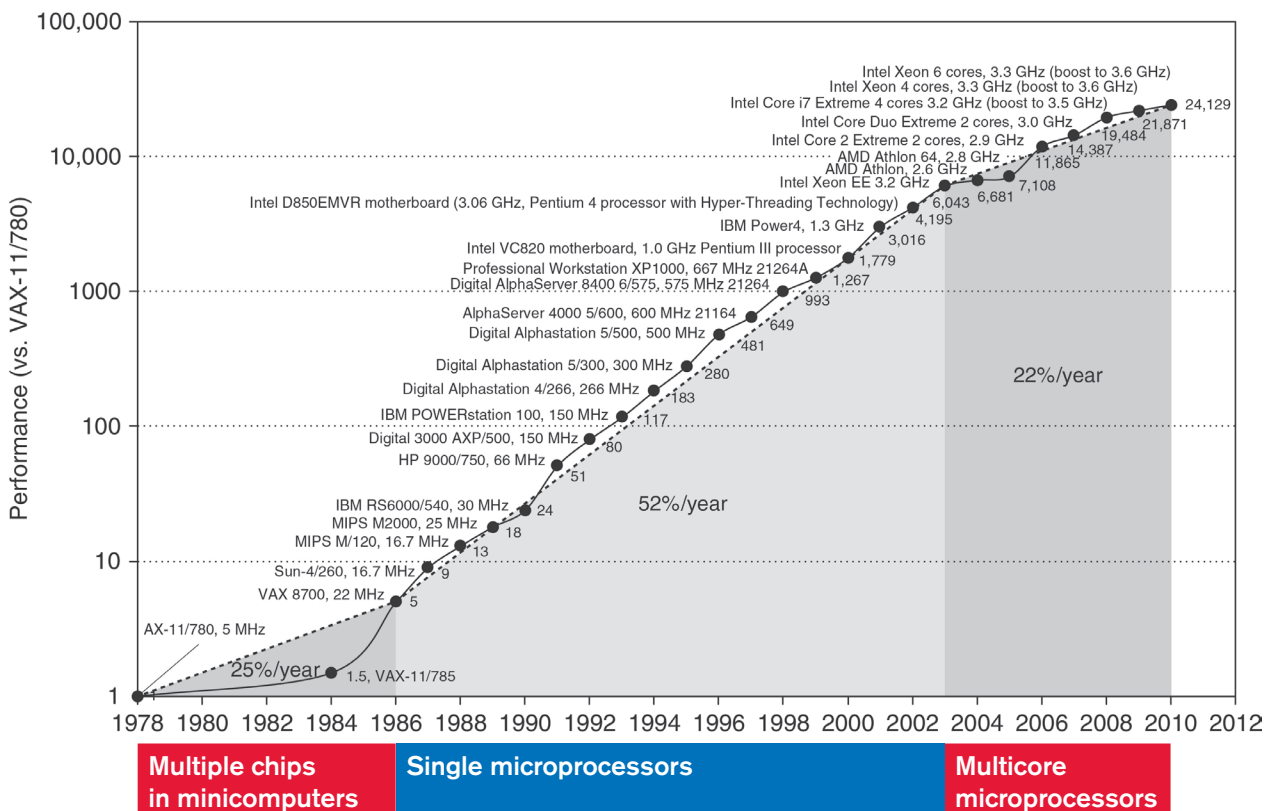
Advanced computing is the systematic use and development of domestic high-end computer hardware, operating and applications software, data management and analytics, visualization tools, and necessary infrastructure, talent and knowledge to exploit these capabilities to solve science, engineering, industrial 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%20Files/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 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.

Findings from the BUILD 1— Pittsburgh, PA

Executive Summary

On November 7, 2018, the Council on Competitiveness (Council) and the University of Pittsburgh co-hosted the inaugural Building University-Industry-Laboratory Dialogue (BUILD) for Advanced Computing at the University of Pittsburgh in Pittsburgh, PA. This initiative is being funded by the National Science Foundation (NSF) as part of a three-dialogue series to present to NSF several, concrete new-to-the-world PPP models. These advanced computing models will support the National Strategic Computing Initiative (NSCI) overseen by the Joint Program Office for Strategic Computing (JPO-SC).

More than 40 participants attended the event, hailing from industry, academia and government. The attendees had diverse subject-matter expertise in advanced computing and PPPs.

Important thematic takeaways from the day's conversations include:

- Grand challenges in advanced computing are a unique abstract organizing mechanism for exploring potential PPP models.
- Further work is needed to bridge gaps between hardware and software, especially user requirements and trends in research and development (R&D).
- Limited sharing of relevant data across government, industry and academia has impeded collaboration and cross-disciplinary research.



Attendees had the opportunity to tour the Cathedral of Learning during lunch.

Framing Thoughts

BUILD seeks to rethink cyberinfrastructure in light of technological disruptions, such as the dominance of data, machine learning and AI, among other fields that are radically reshaping the computing landscape and society at large.

Participants from across industry, academia and government gathered at the University of Pittsburgh—in collaboration with Carnegie Mellon University—for the first of three dialogues to discuss how applications of advanced computing technologies can improve industrial productivity and support federal missions in scientific discovery, national security and economic competitiveness in the United States.

The U.S. science and engineering ecosystem serves as a bedrock of economic prosperity and national security. The United States is entering a new era of science and engineering, anchored by observa-



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; Mr. Chad Evans, Executive Vice President, Council on Competitiveness.

“The Council has been the launchpad of a series of private sector-led efforts and PPPs to advance the mission of out-competing by out-computing.”

Mr. Chad Evans

Executive Vice President
Council on Competitiveness

tion and analytics and transformed by computation and data. Access to advanced cyberinfrastructure—including high performance computational resources, storage capabilities, high-speed networks and new software systems and AI-based systems—has become an increasingly critical component of the science and engineering ecosystem and is expanding every field of inquiry, with a direct impact on national innovation capabilities. This new era is pushed by advances in computation and data-intensive techniques and is pulled by the expanding complexity, scope and scale of today’s national and global priorities.

To address this and enhance competitiveness, the United States must become more agile and adept at collaboration at the intersection of industry, academia and government. Building PPPs—perhaps multi-agency partnerships—can be both difficult and uncharacteristic in terms of an institution’s usual external engagement. However, cardinal successes for advancing shared innovation potential revolve around a mixture of both mutual benefit and mutual exploitation of other sectors’ strengths. The heart of the task at hand is to identify grand challenges that can bring people together in a way that overrides the natural difficulties inherent in partnerships.



Dr. Farnam Jahanian, President, Carnegie Mellon University, center, shares his opening remarks with attendees.



The Honorable Patrick D. Gallagher, President, right, University of Pittsburgh shares his opening remarks with attendees.

In the traditional advanced computing space, the physical machines functioned as the central element of partnerships. Hardware became the shared object that served to pull various stakeholders together due to its complicated and costly nature. Today, the problems themselves unite different sectors, organizations and actors.

Government funding has become increasingly tied to efforts that seek to solve what are deemed as grand societal challenges. The extent to which a program or partnership looks to address core societal needs has become a key factor in resource allocation. As a result, a problem-centered approach that looks at challenges that can only be solved by including

HPC and other capabilities offers a different type of collaboration infrastructure than a machine-, technology- or infrastructure-centered approach.

Recognizing that investments in the United States in research and education have returned exceptional dividends to the nation, it is essential that this effort looks for ways to leverage investment in the advanced computing space to create a thriving discovery and innovation ecosystem—the foundation of sustained economic prosperity and national security. Advanced computing serves as a key driver of competitiveness and economic growth, especially in an increasingly global market, and—as a key component of the innovation ecosystem—is crucial to achieving national and societal priorities.

Why Pittsburgh?

Pittsburgh was strategically selected as the location for the inaugural BUILD. The city has undergone a remarkable transformation centered around knowledge and innovation in recent years. The transition has been mostly university-centric, with the University of Pittsburgh and Carnegie Mellon University as driving forces behind Pittsburgh's evolution from a heavily manufacturing-based economy to one built around healthcare and innovation.

Partnerships and collaboration are also at the core of Pittsburgh's innovation DNA. The Pittsburgh Supercomputing Center (PSC)—a joint effort of Carnegie Mellon University and the University of Pittsburgh—is perhaps the most prominent example. Established in 1986, PSC is supported by several federal agencies, the Commonwealth of Pennsylvania and private industry and is a leading partner in Extreme Science and Engineering Discovery Environment (XSEDE), the National Science Foundation cyberinfrastructure program. In 2014, PSC deployed BRIDGES, a pioneering new national resource funded by the NSF that addresses the convergence of AI, HPC and data.

As a city that has recently transformed into an innovation hub, Pittsburgh provided a strong starting point for this progressive dialogue series.

“Our investments in research and education have returned exceptional dividends to the nation. Thriving discovery in an innovation ecosystem is the foundation of sustained economic prosperity, security, competitiveness, sustainable economic growth and is crucial to achieving national and societal priorities. There's no place better for a kickoff meeting than here.”

Dr. Farnam Jahanian
President
Carnegie Mellon University

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 NSF as one of three lead agencies, working in conjunction with the U.S. Department of Defense (DoD) and the U.S. Department of Energy (DOE). The NSCI calls on NSF to play a leadership role in scientific discovery advances, the broader HPC ecosystem for scientific discovery and workforce development. The 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.

NSF primarily focuses on the second, third and fourth objectives and will contribute to basic research toward extreme-scale computing (first objective) and strengthening public-private collaborations through existing programs (fifth objective).

HPC is particularly relevant in three particular domains of focus for the three lead agencies (NSF, DoD and DOE): industrial competitiveness, national security and science and engineering.



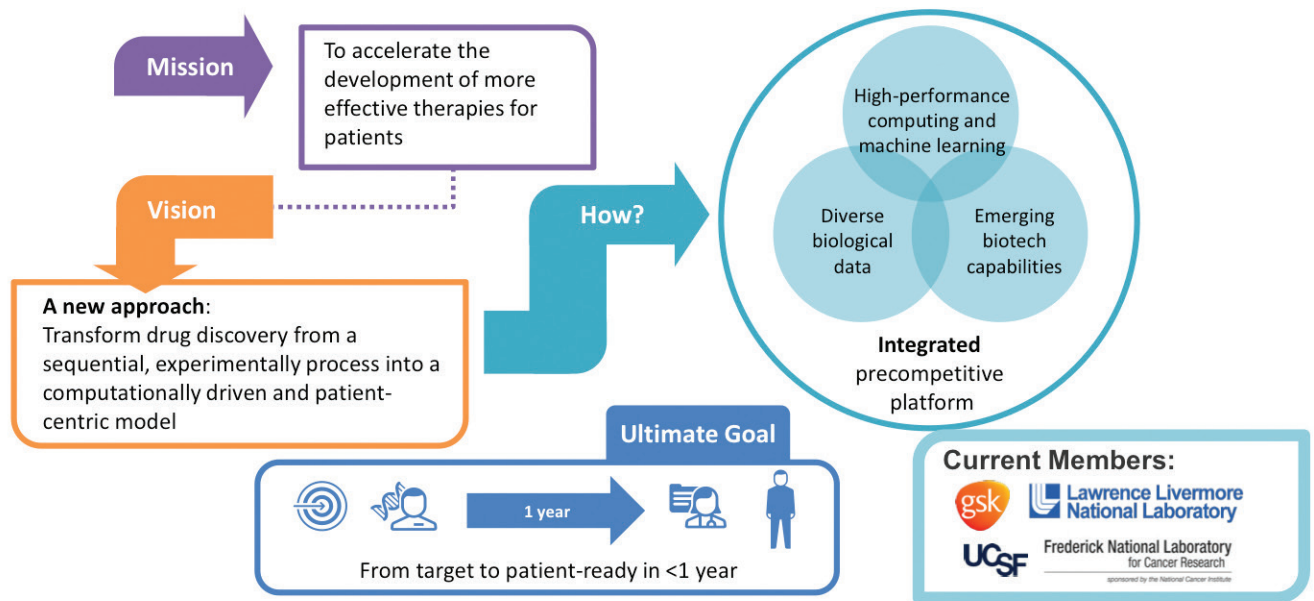
Dr. Tsengdar Lee, High-End Computing Portfolio Manager, NASA; Mr. Mark Sims, Co-Chair, Joint Program Office for Strategic Computing, Department of Defense; Dr. Manish Parashar, Office Director, Office of Advanced Cyber-infrastructure, National Science Foundation and Co-Chair, Joint Program Office for Strategic Computing.

Participants were fortunate to hear directly from government leaders involved in the NSCI about the necessity of BUILD and the impact the BUILD Series will have on future NSCI work. Many participants noted the importance of PPPs in advanced computing. They cited the need for federal funding support, data sharing and retrofitting to find new applications in research and the highly intersectional natures of many of these fields (AI, deep learning, neural networking).

The different requirements for hardware and software quickly emerged as a foundational topic for the day. Some attendees stressed that software was the problem, while others asserted that advances in hardware were outpacing advances in software algorithms.

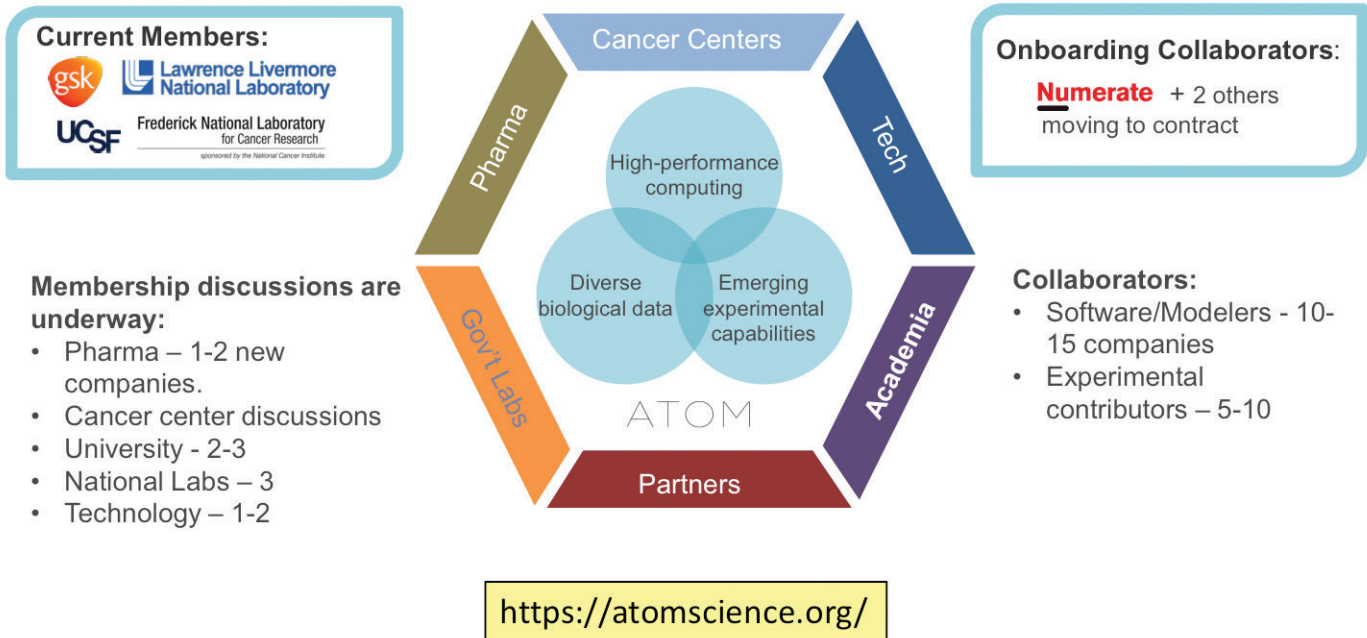
Accelerating Therapeutics for Opportunities in Medicine (ATOM)

A Precompetitive, Public-Private Consortium



ATOM ecosystem is growing

Partnering to build a precompetitive drug discovery ecosystem



NSCI: Contributing Agencies



• Lead Agencies

- DOE: Office of Science and NNSA collaboration on Exascale for their missions in simulation and analytics
- NSF: HPC Ecosystem for science; workforce development
- DOD: Advanced Analytics to support its mission



• R&D Agencies

- IARPA: Alternatives to standard semiconductor technologies
- NIST: Measurement science for future computing technologies



• Deployment Agencies: NASA, NIH, FBI, DHS, NOAA

- Participate based on their missions
- Participate in deployment, workforce development, and innovative collaborations.

All attendees agreed on the importance of messaging clarity when communicating with policymakers about advanced computing topics, such as AI and HPC. Given general low levels of technical understanding among policymakers, there was a consensus that more effective, clear articulation of funding and infrastructure needs is essential for future success in the advanced computing space.

Additionally, attendees discussed how the year-to-year impact of funding could vary in the near-future compared to the long term. This tied into an earlier conversation about securing long-term advantages in competitiveness by driving technological research toward solving specific problems in terms of emphasizing hardware versus software.

The Future of Advanced Computing

Participants were presented with an innovative PPP model that is grounded in a historical overview of recent developments in advanced computing while also looking ahead at potentialities and possibilities in an era of disruptive change.

The most important ongoing development is the approach toward the end of Moore's Law, driven by looming functional limits to miniaturization in the time frame of 2020–2025 regarding the number and size of transistors per chip. Dennard scaling—i.e. as transistors shrink, voltage and current shrink as well, such that power density remains constant—combined with Moore's law to dramatically increase the number of transistors on a chip while maintaining the same power consumption, ended in 2004.

“We need to rethink what ‘advanced computing’ means. How do we expand it to include the spectrum of both actors and technical requirements? This is another area where PPPs help; they're not unique to one actor so natural win-wins can emerge for all.”

Dr. Manish Parashar

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

The end of Dennard scaling in 2004 might be related to a blip in productivity growth during the same period, which historically has grown in the past 30 years but is now no longer on an upward trend. Productivity growth was identified as the relevant economic measure because it leads to higher standards of living.

Looking at the impact of advanced computing on economic growth, one important fact shared during this session was the statistic that since 1974, one-third of annual laboratory productivity growth has come from IT.

“Economic productivity is the story of prosperity.”

Dr. Neil Thompson

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

Conceptually, this session was grounded in the idea of the computer as a general-purpose technology that abides 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, every component of this cycle is currently experiencing disruption. There has been a slowdown in technological advances, fewer users are adopting new technologies and computing is increasingly more challenging to finance. This has led to a fragmentation/breaking in the computing ecosystem. For example, the performance improvement of microprocessors has slowed down. Additionally, the average replacement age for a computer has risen from four years to five to six years.

People 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 ~13 percent per year. This is compounded by market consolidation, leading to fewer new innovative players in the computing space.

Two general options/paths were highlighted during this session regarding the future of computing.

Option 1 is greater/more specialization of chips. Greater specialization is attractive when CPUs are slow to improve, because this option involves the significant speed-up of processors, for example, an NVIDIA GPU is especially relevant for deep machine learning.

This option would accelerate existing trends, leading to a fracturing of computing into fields such as universal/general computing, bitcoin, deep learning and others. The contrast presented was that while the old model was built around the idea that “a rising tide lifts all boats,” the new model would be built around the concept of fast and slow “lanes,” with clear winners and losers in the computing ecosystem.

Option 2 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 these technologies are indeed the future, it was argued that there is not sufficient investment in them now regarding R&D. Additionally, the benefit of specialization is mostly one-time, meaning that increased adoption of specialized chips could hurt everyone in the computing space in the long run.

One conclusion drawn was that the only way to solve long-term problems in computing is to invest significantly more in these next/emerging technologies. However, attendees did not uniformly agree with this argument, offering, for example, that better application and utilization of existing frameworks and technologies could be sufficient if done effectively.

PPPs are uniquely positioned at the nexus of these issues and challenges due to their ability to bring together multiple, disparate stakeholders. They provide an essential function by setting up cross-disciplinary best practices that help to prevent divergence/fracturing in the computing ecosystem, while simultaneously promoting widespread, adoption of new technologies.

One institution highlighted during this session that is at the forefront of exploring many of these problems and developments in advanced computing was

the Pittsburgh Supercomputing Center (PSC), a joint venture of the University of Pittsburgh and Carnegie Mellon University.

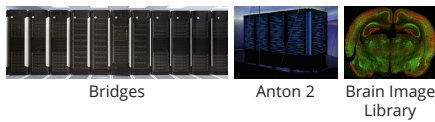
PSC identified hardware challenges like energy, latency and concurrency, and identified software challenges such as algorithms, legacy applications, concurrency, verification and validation, and education.

PSC additionally identified the following as general trends in the advanced computing space: the convergence of HPC, AI and data; the democratization of data, which enables transformative, multidisciplinary

PSC

National service provider for research and discovery

- Bridges, Anton 2, Brain Image Library, Open Compass, XSEDE, Olympus



Research institution advancing knowledge through converged HPC, AI, and Big Data

- ~30 active funded projects



Education and training

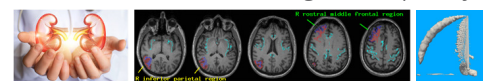
- Lead national & local workshops
- Support courses at CMU and elsewhere
- Teaching, thesis committees, interns



PSC is a joint effort of Carnegie Mellon University and the University of Pittsburgh.
 32 years of leadership in HPC, HPDA, and computational science.
 20 HPC systems, 9 of which were the first or unique.
Pioneering the convergence of AI + HPC + data.

Active member in the CMU and Pitt communities

- Research collaborations
- Colocation for lower cost and greater capability



Networking and security

- Networking & security service provider (3ROX)
- Research networking



Advise and support industry

- Training, access to advanced resources, collaborative research



research; the emergence of new technologies for memory and computation; interoperability between HPC and the cloud; and increasing concurrency.

The following were also identified by PSC as challenges in the advanced computing space: partnerships to establish at-scale use cases to inform technology; early investment in advanced technologies to drive beyond commodity markets; education and training at both the university and professional levels; algorithms, especially for neuromorphic and quantum computing; programming models and frameworks for high concurrency, neuromorphic and quantum computing; and application development, (re)implementation and scaling.

PPP Deep Dive: Computing and Information Technology

This session focused on how possible PPP models can be built in the general computing and information technology (IT) spaces.

Several general themes that attendees converged on during this session were the idea of heterogeneity in requirements, applied use of HPC, integration of applications and overall disruption due to the end of Moore's Law.

One idea underpinning many of these topics is the concept that the basic computing paradigm, as envisioned decades ago, has effectively "run out of gas," and that therefore new paradigms are necessary. However, this is an opportune era of incredible energy and innovation in which to conceptualize and develop these paradigms. This suggests that a grand challenge model for developing PPPs would be a practical approach, grounded around co-nucleation



Attendees engaging in discussions during morning sessions.

around key high-level issues in the computing ecosystem and broad enough to attract sufficient interest from all relevant stakeholders.

At the software level, opportunities were explored by attendees regarding how to curate data, understanding the intersections between government and business, cloud infrastructure and general cyber-infrastructure. These conversations echoed points made earlier in the day about the risks of fragmentation caused by specialization. In particular, this question continued to resonate, because when looking at PPPs, scalability is essential. Focusing exclusively on hardware or software is, by definition, not scalable.

Attendees additionally discussed how data sharing is a key issue when looking at segmentation in the exascale computing space. Unlike in many other countries, the United States has a highly decentralized system of data collection and storage in terms of machine learning training data, ranging from personal factors in health and vital statistics to other

“The landscape focused on at-scale partnerships on grand challenges is an opportunity area for advanced computing.”

Dr. Rob Rutenbar

Senior Vice Chancellor for Research
University of Pittsburgh

sources. This means that from a global competitiveness perspective, the United States is at a disadvantage. However, PPPs can help enable data sharing in a way that leverages heterogeneity. The problem is how to set up economic motivations to come into these ecosystems, especially when there is resistance to disruptive technologies in software in particular.

Conversations also developed around the importance of supporting basic R&D and preventing “short-termism” regarding funding and the realization of relative economic benefits. The discussion also returned to earlier highlighting of the importance of avoiding the development of a computing ecosystem that is built fundamentally around the “haves” and the “have-nots,” especially because of the presence of highly-specialized players (such as climate scientists) who will be left behind if the long-term benefit of next-generation technologies is not realized due to insufficient funding.

“How can we pilot a new system while we reinvent what computing infrastructure looks like at the bottom? In the healthcare space, there’s an opportunity to partner with the private sector to figure this out.”

Dr. Shivdev Rao

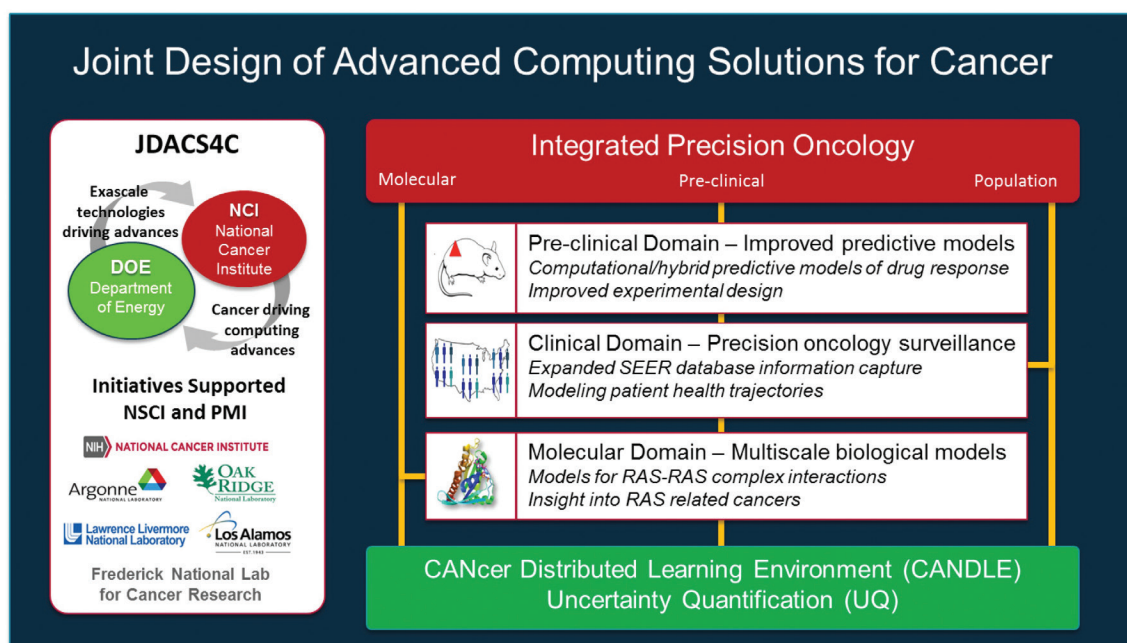
Executive Vice President
UPMC Enterprises

PPP Deep Dive: Health and Wellness

Five specific items were identified in discussion during this session as being essential to include in the development of successful PPPs: technology, timing, talent, transformation and translation.

- **Technology** is foundational to looking at PPP models in advanced computing in its context as a disruptor of existing business practices, and processes and research priorities.
- **Timing** is important because different projects and technologies have different horizons of viability at the research and commercial levels.
- **Talent** was universally described by attendees as being a pressing issue because of a lack of qualified engineers and scientists equipped to program, handle and think through advanced computing issues, as well as keeping current staff up-to-date with new technologies/skills.

Joint NIH-DOE Partnership to Support NSCI



- **Transformation** is critical for organizational and product optimization.
- **Translation** is essential for the development of foundational science into practical applications.

Attendees also engaged in a robust discussion about trends in the healthcare space relating to advanced computing. Several macro-level trends were identified: more bundling with integrated delivery networks, vertical integration at all levels of care and IT infrastructure, direct-to-consumer business models

increasing in popularity, and the “consumerization” of the overall healthcare space to focus on patient needs.

The healthcare space was also identified as being a prime location for analytics opportunities in machine learning due to the sheer volume of raw data available. This availability, however, must be weighed against patient data privacy concerns and cost considerations.

Patient health considerations (and diagnoses) were also discussed as part of the general trend of consumers seeking greater ownership over their health-care. This can lead to bias in the data depending on the predictability of patient outcomes and self-reporting/self-diagnosing. As part of a broader issue of trust in clinical experts, attendees agreed that there was a need in this space to reconcile these conflicting trends as part of any PPP effort.

PPP Deep Dive: Artificial Intelligence

One question that attendees grappled with in this session was how to avoid the quintessential trap of “admiring the problem” rather than addressing the issues. Sufficient resources and stakeholder engagement is not enough; without actionable PPP models, no progress will be made. The uniform availability of advanced computing resources was highlighted as a critical component of any PPP plan in the AI space.

Attendees also were exposed to a range of technical information and top-level assessment regarding the current and future positioning of AI as it relates to the advanced computing ecosystem. In particular, a substantive, deep dive on deep learning techniques provided important insights into some of the theoretical and practical opportunities and risks in this space.

Deep learning, relying on extensive amounts of data for systemic training and algorithmic optimization, can incorporate many hypotheses because of its complex (not linear) structuring. However, the possibility of low-quality training data, the risks of picking up on subtle patterns, and adversarial manipulation of inputs are all real risks that can affect the integrity and quality of deep learning-generated analyses.

“There are many high-societal benefitting applications, dependent on sensitive data, that are AI-empowered and based on advanced computing as an engine. If we don’t stand up partnerships, key problems will remain unsolved.”

Mr. Michael Garris

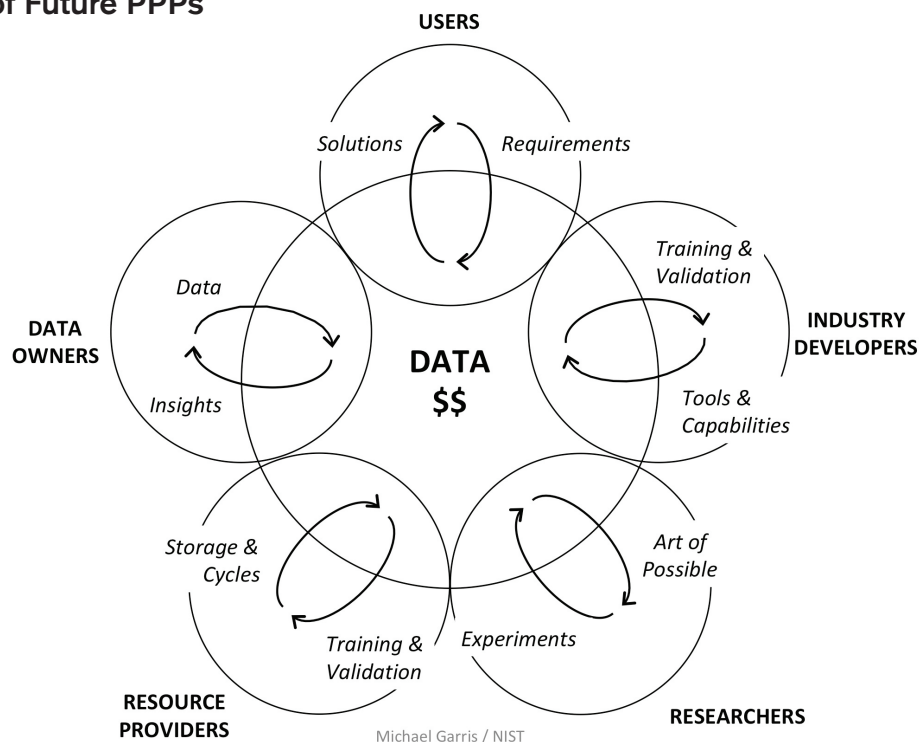
Senior Scientist and Founding Chair of the NIST AI Community of Interest
National Institute of Standards and Technology

One critical question that emerged during this session was whether or not a firm-level competitive advantage generated by using deep learning could be applied at the national level. Some attendees believed that the existence of feedback loops would make such an assertion true at the societal level, although it would be difficult to prove definitively.

Attendees additionally had the opportunity to hear about and discuss the data dissemination practices of the federal government. In particular, there were conversations about safeguards around classes of data and how these restrictions can be both advantageous for citizen/consumer privacy and limiting for researchers interested in the sort of large-scale analysis that could reveal any national competitive advantages from deep learning. This could lead to a possible PPP model built around creating challenge problems regarding research-technical gaps, and the broader advanced computing community could then be invited to come up with solutions.

Data at the Heart of Future PPPs

Source: Michael Garris / NIST



1

PPP Brainstorming Breakouts Summaries

Breakout group led by Council on Competitiveness Executive Vice President Chad Evans

The breakout group conversation landed on three important topics of discussion likely to impact the development of any PPP model, expending significant effort on education, technology proliferation and exploring how to bound a new PPP model.

1. On education, there is a large-scale foundational question of whether current computer science education standards and curricula are inhibiting U.S. competitiveness by being too narrowly focused. Programming is just one part of the
2. Concerning technology proliferation, co-nucleation of hardware and software will be essential to developing and sustaining business models in advanced computing that have significant returns on investment and that engage with dependencies in the supply chain.

skillset; the future of advanced computing needs to be driven by engineers, scientists, and developers who have been trained how to solve problems with parallel thinking and understand the world of user requirements. The proliferation of coding academies is of particular concern since the trend seems to reward memorization/rote learning rather than logical problem-solving and ensuring knowledge of the real user-based world.

3. In attempting to construct a new PPP model, participants pulled from their experiences, building off a corporate accelerator model and attempting to customize to suit the particular needs of a given PPP. The corporate accelerator model would encourage large companies to connect with several startups at once. The deliverable would be to present the corporation with an idea they would not have thought of themselves, but that they have the capability to execute successfully due to their resources. Incentives would be built around using the government's national laboratories and academic resources to achieve commercial success. Such a model would allow each corporation to create its own rules with the desired setup and scope of work.

Breakout group led by University of Pittsburgh Vice Chancellor for Economic Partnerships Rebecca Bagley

This breakout session discussed building a new, broadly applicable PPP model by focusing on areas of commonality across public and private stakeholders. Participants signaled interest in architecting PPP models to serve PPP participants at any level of technological capacity and establishing regularly scheduled deliverables as a means to maintain interest and enthusiasm.

This breakout session identified three key themes to be addressed for long-standing success for new PPP models in the advanced computing space:

1. Talent—is current computer science education inhibiting competitiveness by being too narrowly focused? Many programs, including computer science “bootcamps,” develop coding skills at the expense of skills that will aid in long-term career development. Computer science graduates must be equipped with not only the skills to write programs, but knowledge of the users’ world as well, sufficient to build systems in response to real-world issues.
2. Focus on the supply chain and business models—in reviewing the technological landscape today, participants noted many companies focus on either hardware or software, with few who have built a vertical supply chain capable of co-nucleating hardware and software. From a national strategic objective, the United States is exposed to risk by the disassociation of these technologies.
3. Building PPPs through competition—a market failure exists between small, innovative startups and larger companies who have the resources to grow and validate new technologies. This is prime territory for the public sector, which can provide the incentives to develop new partnerships and draw the interest of corporations through new engagement opportunities between government laboratories, academic research institutions and the private sector to raise the likelihood of new technologies to achieve commercial success.

The Path Forward

The day's discussions surfaced several important and concrete areas where existing advanced computing partnerships have made great strides in promoting public good. Advanced computing partnerships have enhanced information technology capacities to track, sense and analyze data; advanced computing in healthcare and wellness is leading to better patient outcomes through improved diagnostic tools, though also introducing new dangers as healthcare consumers seek greater ownership over their health; and dynamic changes to the future capabilities of computing's potential impact through the convergence of existing and new-to-the-world technologies manifesting as AI and machine learning.

The growth of new and existing industries through advanced computing partnerships underscores the importance of new models for engagement to capture a wider cross-section of stakeholders and perspectives. Conversation raised one such model, identifying specialization as a path forward for computing, while new and different technologies mature to market readiness. This model will continue to be refined in future BUILD for Advanced Computing events. In the spring of 2019, the Council will host the next dialogue at the University of California, San Diego in San Diego, CA, to continue the conversations started in Pittsburgh.

“This group has a unique role that following dialogues won't have, being the first one. We're excited about the fact that we'll have an outsized voice in shaping this opportunity.”

The Honorable Patrick D. Gallagher
Chancellor
University of Pittsburgh

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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