BUILD for Advanced Computing

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San Diego, CA

Post Report

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Agenda

MORNING

8:30 Registration and Light Breakfast

9:00 Welcome Remarks and Roundtable Introductions

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

Dr. Michael Norman
Director
San Diego Supercomputer Center

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

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

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

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

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

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

10:30 Coffee Break

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

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

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

Mr. Chad Evans
Executive Vice President
Council on Competitiveness

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

PPP CONCEPT 1

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

AFTERNOON

12:00 Lunch Break and Data Center Tours

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

PPP CONCEPT 2

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

2:00 Roundtable Review and Refine

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

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

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

2:30 Coffee Break

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

Lessons from California in Predicting and Mitigating Natural Disasters

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

4:00 PPP Deep Dive: Health and Wellness

Dr. Guna Rajagopal
Vice President, Computational Sciences
Janssen

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

5:00 Closing Comments and The Path Forward

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

Dr. Michael Norman
Director
San Diego Supercomputer Center

5:15 Closing Reception

6:15 Reception Ends

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 high performance computing (HPC) as a foundational technology and business asset for improving U.S. productivity and prosperity.

"Productivity is the ultimate metric, and computing power helps advance productivity."

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

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. 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.

"We need a focus on talent creation and creating expertise in the United States."

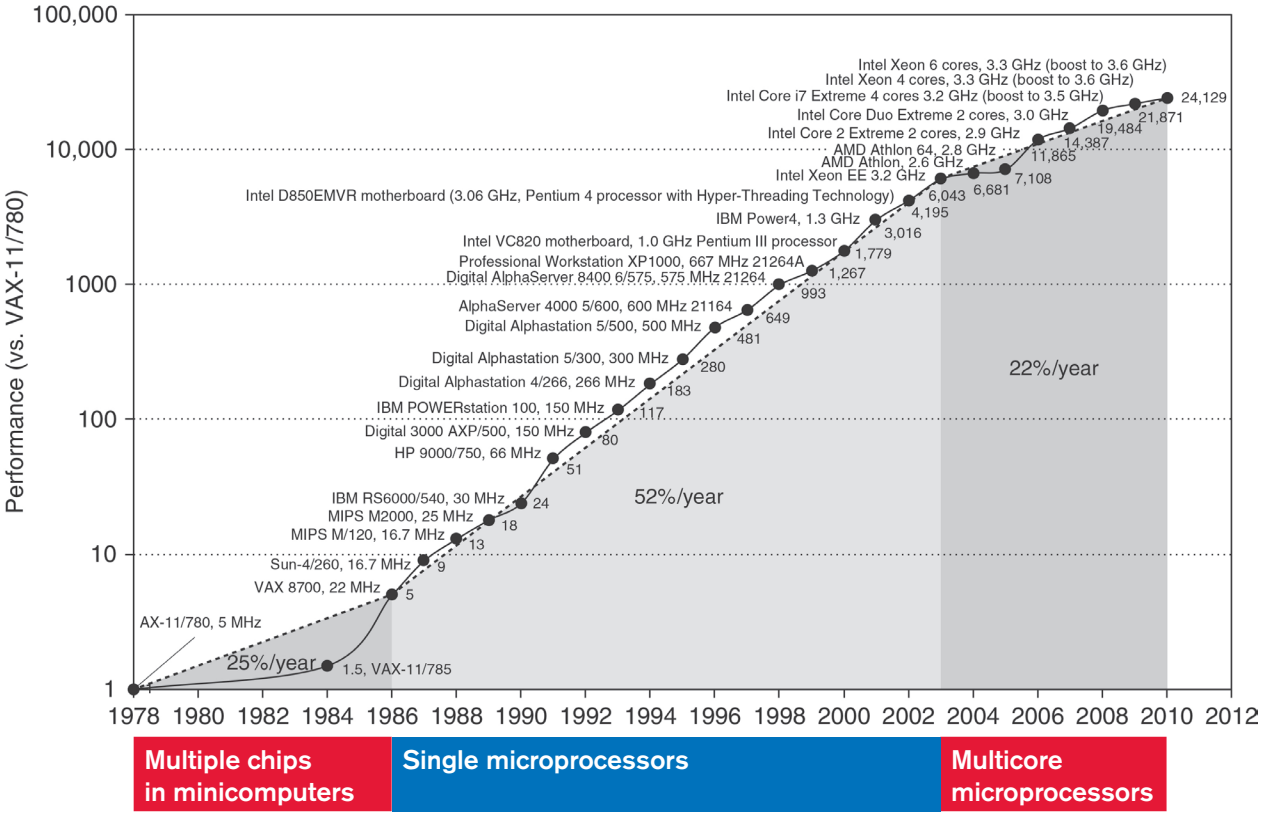
Dr. Manish Parashar
Office Director, Office of Advanced Cyberinfrastructure
National Science Foundation, and
Co-Chair, Joint Program Office for Strategic Computing

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.

Computing Performance Improvement Slowing (SPECInt Benchmark)

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



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 toward extreme-scale computing (objective one) and strengthening public-private collaborations through existing programs (objective five).

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

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://engcs.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 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.

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;

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

Public-Private Partnership Characteristics

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

- 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 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.

Findings from the BUILD 2– San Diego, CA

Executive Summary

BUILD 2 participants in front of the San Diego Supercomputer Center in San Diego, CA.

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

BUILD for Advanced Computing is a three-part progressive dialogue series to deliver 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 second dialogue built on the work of the inaugural dialogue held at the University of Pittsburgh in November 2018, sharpening two specific PPP models—respectively focusing on specialized chip development and nationally trusted microelectronics development—as well as delving into San Diego's work in the local innovation ecosystem and top-level partnership takeaways in the fields of health and biotechnology.

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

"The driving force of innovation during the Cold War was geopolitical and philosophical. Now, the nature of competition has changed because of global market dynamics with China and other countries."

Ms. Kathy Trimble
Vice President
Council on Competitiveness

Dialogue participants each had the opportunity to introduce themselves and share their thoughts on what advanced computing meant to them and their organizations.

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:

- 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 the entire ecosystem of providing essential technical knowledge and activating interest in science and technology in the educational system, starting at an early age.
- Finally, the United States has a significant skills gap in fields such as advanced computing that will weaken its ability to compete globally unless this underlying issue in the educational system is addressed.

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

"Moore's Law for supercomputing will not be ending; there's an endless frontier."

Dr. Michael Norman
Director
San Diego Supercomputer Center

Dr. Michael Norman, Director, San Diego Supercomputer Center; and Dr. Albert Pisano, Dean, Jacobs School of Engineering, University of California San Diego.

Framing Thoughts

Dialogue leaders the Honorable Deborah L. Wince-Smith, President & CEO, Council on Competitiveness; Michael Norman, Director, San Diego Supercomputer Center; and Sandra Brown, Vice Chancellor for Research, University of California San Diego, opened the conversation at BUILD 2 with a recognition that advanced computing stands at the precipice of change, both in the power of advanced computing to transform future economics and for its representation of an "endless frontier"—the idea that even with the upcoming end of Moore's Law for circuitry, supercomputing as a field retains significant growth potential independent of computing's pending physical challenges. This optimism about advanced computing's future potential set the tone for the day's discussions in terms of the sheer number of possibilities for advanced computing in the coming years and the urgency of applying these revolutions in computing to advance U.S. security and global computing leadership.

Dialogue leaders also noted the diversity of constituencies represented in the dialogue, reflecting the depth and breadth of the expertise in the fields of advanced computing and PPPs. Bringing to the table different perspectives is critical to solving new challenges, and the challenge set forth to participants was one to which they were well-suited. The group was tasked by dialogue leaders to develop new-to-the-world models for public private partnership, thinking critically on how to engage a broad cross-section of advanced computing stakeholders to advance the mission of the National Strategic Computing Initiative.

Why San Diego?

San Diego was an important stop for this conversation. The city and broader region have undergone an incredible evolution, from a 20th century defense-focused town to a global, urban center leading in telecommunications, computing, biotechnology and other domains defining the future of 21st century innovation. At the heart of this transformation has been the University of California San Diego and growth of private industry, who continue to build new and lasting partnerships with global effect.

The growth of San Diego as one of the world's true innovation hubs was built in part by the San Diego Supercomputer Center, an organized research unit of UC San Diego first established in 1985 as one of the nation's first supercomputer centers under a cooperative agreement by NSF, the UC San Diego and GA Technologies. The San Diego Supercomputer Center is also a partner in the Extreme Science and Engineering Discovery Environment, the most advanced collection of integrated digital resources and services in the world.

The centralization of this wealth of knowledge and capability continues to grow economic activity and partnerships, providing a strong backdrop for the second dialogue in the BUILD Series.

Bridging from BUILD 1: A Deep Dive into Potential PPP Models to Advance the Future of Microelectronics

The first dialogue co-hosted by the Council and the University of Pittsburgh in Pittsburgh, PA was intended to set the stage for this dialogue series by outlining initiative goals, level-setting in terms of expectations for dialogue and deliverable timing for the series and final report to NSF, generating initial leads for potential PPP models and highlighting the Pittsburgh innovation ecosystem.

Two models emerged from BUILD 1. The first honed through conversation and another drawn from the Council's longstanding collaboration with universities and national laboratories. The second dialogue in San Diego built on these PPP models by applying new and different perspectives to similar conversations from Pittsburgh, stress-testing and diving deeper into each model to showcase additional areas of engagement and collaboration between stakeholders.

PPP Concept 1: Accelerators for American Computing

One major takeaway from the inaugural BUILD was the emergence of a PPP model concept focusing on driving growth in computer performance after Moore's Law, which is projected to end in 2022. Moore's Law and other technical developments drove decades-long miniaturization for general-purpose CPUs, leading information technology to represent one-third of annual labor productivity growth since 1974. The creation of more powerful, smaller and less expensive processing power enabled businesses to capture new sources of value through new business models or the application of new technology across existing business lines.

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.

However, the increasing difficulty and soaring cost of producing more powerful and efficient processing power bore out in the productivity data. Cost-adjusted computing performance improvements slowed from 48 percent to 8 percent respectively in the periods of 2000–2004 to 2008–2013 as Dennard scaling—i.e. as transistors shrink, voltage and current shrink as well, such that power density remains constant, but this no longer held true in transistors developed by the mid-2000s—and Moore's Law began to slow. Around this time, chip manufacturers began to move away from single-core chips toward multi-core chips, giving rise to parallel processing as a means to achieve new sources of productivity gains. Starting in the mid-2000s, firms with more parallel software had better productivity growth. A productivity gap between more and less parallelism emerged in the computing space. Significant speed gains remain possible by developing special-purpose CPUs, targeted for specialized tasks.

"We should be aware of the importance of end-users when discussing high performance computing. There's a need for out-of-the-box thinking when looking at different models for private sector investment."

Mr. Gora Datta
Board Member
IEEE Southern California Council

"Advanced computing is linked to national priorities."

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

In response, 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.

This slowing down of computing performance improvement intersects with what was described as the cycle of 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 positive spill-overs from those who develop the chips to industries and sectors. The development of specialized chips via collaboration between industry partners, academia, and the government could benefit society at large.

Feedback on this proposed model was generally positive. A specific point of pushback worth noting is the assertion that generalized architectures are preferable to specialized architectures for general-purpose computing unless the demand is very high for a particular specialized chip. The point of contention surrounds the timing of when and how the economics of this market are changing, such that promoting this PPP's specialized chips would be both economically necessary and economically viable.

Participants also made clear that the private sector already engages in all steps of this process, so the proposed breakdown of responsibilities might need to be adjusted to reflect that.

Another suggestion was to switch to "building blocks" for chip proposal and validation rather than the actual processors. This would allow for reconfigurability that targets specialized functions. It wouldn't be a one-time win, but would instead provide a framework for multiple additional designs and synergies. It would be akin to an open-source hardware environment/domain.

In response, participants cautioned not to take actions that would take away from development of general-purpose processors, reflecting that many computing applications continue to benefit from non-specialized processors where computing algorithms demand a variety of processing "styles" to take place in sequential order—rather than computing applications where processing can be batched to take advantage of specialized processors.

PPP Concept 2: Beyond CMOS Electronics—Challenges and Opportunities

The first PPP model focused on the need to point technology evolution toward specialization to spur growth, while the second PPP model looks to transform the underpinning technology for long-term growth. The complementary metal-oxide-semiconductor (CMOS) technology at the heart of mainstream integrated circuits is expected to lead to an unsustainable and dramatic growth in energy demand as emerging technologies and applications increase in scale. The second PPP model conceptualized a national effort at the scale of a presidential initiative and focused on opportunities for the United States to overcome a challenge of this scale. The PPP seeks to answer a question at the heart of future U.S. technology leadership: How can the United States accelerate the pace of innovation and commercialization to maintain global leadership in semiconductors and advanced computing technologies, such as autonomous vehicles, remote intel-

Speaking from the podium: Dr. Ramamoorthy Ramesh, Purnendu Chatterjee Endowed Chair in Energy Technologies, Department of Materials Science & Engineering University of California, Berkeley.

ligence, AI/machine learning and virtual/augmented reality, in the face of rising dominance by other countries in this space?

No high-probability candidate to replace mainstream CMOS technology exists, and therefore multiple paths must be pursued to ensure future technologies to flourish. The United States is stagnating at a critical technology transition while other nations are doubling down on innovation. A sustained innovation surge is needed.

The critical gap is in the ability to scale promising R&D results to de-risk industry investment. The trifecta of sciences addressed by the model would, therefore, be fundamental science, computing science and manufacturing science to address a broad range of research areas and minimize overall risk.

The top-level ambition is to secure U.S. leadership in next-generation electronics and computing by 2025, coordinated under the auspices of the Office of Science and Technology Policy and the Office of Management and Budget as part of a presidential-scale initiative.

The rough outline of the PPP was presented as follows:

- Proposed participants in this partnership would include U.S. Department of Energy, U.S. Department of Defense agencies, Semiconductor Research Corporation, National Science Foundation, National Institute of Standards and Technology, Defense Advanced Research Projects Agency, Intelligence Advanced Research Projects Activity, and Advanced Research Projects Agency-Energy.
- Partnerships would develop between government agencies, industry, academia and the national laboratories.

"With exponential growth in energy consumption energy efficiency will be the next big question in advanced computing."

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

- Three regional institutes would be developed, modeled after the Fraunhofer Institutes in Germany, focusing on applied research.
- The focus would primarily be in the fields of digital electronics, neuromorphic computing and computing for national security.
- The scale would be on the order of $100 million per year for five years per institute.
- 1:2 cost share (Private:Public), and the public share would be divided equally between federal and state governments.
- The institutes would be created through an open national competition.

One critique of this model raised by participants was that it would be too broad to scale and implement effectively. Another point, mentioned earlier in the day as well, is the lack of critical mass in manufacturing capability.

Feedback on this PPP, given its national emphasis, also broached the topic of broader geopolitical positioning in a competitive global economy. In particular, participants noted that the nature of competition has changed since the end of the Cold War. Global market dynamics have led to capitalist economies competing against each other, instead of communist economies; significant foreign direct investment clouds, where invention and innovation value is captured; and supply chains are global in nature, spreading investment and returns from any private entity worldwide.

In an age of long-term, great-power competition with China, the scale of engagement and competition is much broader (compared to, for example, SEMATECH—a PPP to revitalize the U.S. semiconductor industry founded in the mid-1980s as a response to Japanese innovation and market leadership). The success of SEMATECH was discussed, but participants noted that the national effort required by this proposed PPP to develop an entirely new underlying technology is of a vastly different scale and scope.

While participants debated the best method of structuring this PPP, many referenced the likely difficulty of securing bipartisan engagement or funding from Congress and the administration at the level necessary for this PPP model to succeed. Nonetheless, perceived hesitancy on the part of federal lawmakers and agencies should not dissuade stakeholders from engaging in partnerships critical to the nation's future competitiveness.

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

PPP Deep Dive: Predicting and Mitigating Natural Disasters

After presentations on and discussion of the two PPP models that have emerged so far in the BUILD Series, participants had the opportunity to hear about other PPP success stories and possibilities that could help inform the development of additional advanced computing PPP concepts.

One success story is the work that the California Institute for Telecommunications and Information Technology (Calit2)—a research institution jointly run by the University of California San Diego (the San Diego branch is known as the Qualcomm Institute) and the University of California, Irvine—has done in the field of wildfire visualization, tracking, prediction and response coordination leading to the development of the tool "Firemap". In WIFIRE's own words:

To meet growing needs in hazards monitoring and response, the WIFIRE Lab aims to be an all-hazards knowledge cyberinfrastructure, becoming a management layer from the data collection to modeling efforts. We have the only integrated infrastructure that can provide this capability right now and it can be a neutral data resource/partner to any proposed activity. We add value to the raw data and prepare the best data in real-time for any monitoring and modeling effort (along with our own dynamic data-driven models) for research and operational use. The WIFIRE Lab in this capacity has a consortium of UC San Diego organizations and a number of partnerships including the university collaborators, industry partners, fire departments, utilities, State's CalOES and CPUC.

Firemap is a tool developed by WIFIRE researchers to perform data-driven predictive modeling and analysis of fires that have a high potential for rapid spread, and enables what-if analysis of fire scenarios ahead of the time as well as real-time fire forecasting. It also provides easy access to information on past fires, past and current weather conditions as well as weather forecasts, satellite detections and information on vegetation and landscapes from a variety of sources. These are all datasets available on different websites that viewers can now see in one place, achieve programmatic access to via web services, and be used for planning fire response and management of natural resources well ahead of time.

Participants were particularly interested in lessons about collaboration and scalability from WIFIRE that could be applied to semiconductor-focused PPPs. There was also interest in applying these predictive tools to other natural disasters of special and urgent interest nationally and globally due to the accelerating impacts of climate change on the environment.

One lesson is that a novel technology might need to be sufficiently mature and publicized to attract the attention of potential collaborators, as was the case with WIFIRE, when local fire departments reached out to the university partnership expressing interest in working after learning about the system in the news.

PPP Deep Dive: Health and Wellness

Conversation showcasing the range of PPPs in the advanced computing space continued, exploring the realm of health and wellness, explicitly focused on drug discovery and biotechnology. The data landscape was described as revolving around the intersecting nexus of target, compound and patient. Integrating big data, the cloud, analytics and HPC was identified as part of a collaboration between Janssen and the San Diego Supercomputer Center. Janssen's collaboration with the National Institutes of Health in addressing the recent Ebola crisis was also highlighted as an example of how PPPs can help the public sector rapidly access private sector technical and research expertise in times of crisis.

Opportunities in the biotech space were presented as potentially having a more significant immediate impact, as participants referenced the field as being at the forefront of solving major global problems. It creates impactful products delivered by collabora-

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

"The drug discovery data landscape is broadly focused on the target, the compound and the patient."

Dr. Guna Rajagopal
Vice President
Computational Sciences, Janssen

"Biotechnology is being used to solve major global problems, leading to impactful products delivered by collaborative science."

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

tive science, sitting at the intersection of big data, biological research and computing. One reason why the field takes time to develop its products is that the development of new molecules has a significant lag from discovery to application of typically 20 years. Even so, the design and build phases of synthetic biology have largely been automated in recent years, leading to improved efficiencies.

Investment in measurement technology has resulted in a sea of biotechnology data. This ever growing development and proliferation of data—gathered from disparate sources, and from across different industries and sectors—requires the creation of a common set of standards for compiling, reporting, sharing and storing that data. Lack of standardization perpetuates a lack of standardization during the research process—collaboration and partnerships could help address this issue by creating uniformity and a common language for how to organize, curate, label and use this data across industry, academia and government.

Closing Comments and the Path Forward

The Honorable Deborah L. Wince-Smith, President & CEO, Council on Competitiveness; and Mr. Chad Evans, Executive Vice President, Council on Competitiveness.

"Where will we get our 'digital water' in the future?"

Dr. Michael Norman
Director
San Diego Supercomputer Center

Dialogue conversation closed with a review of overarching themes from the day, namely the diminishing domestic capacity to create the building blocks of future advanced computing resources, as well as the importance of developing a talent pipeline able to recognize the importance of and capitalize on advanced computing resources.

A broad takeaway is that the U.S. microelectronics industry is undergoing a period of significant change, amplified by global competition. A useful analogy raised by a participant and captured the imagination of the group was that of "digital water," reflecting the idea that digital infrastructure (which is only increasing in scale, scope and use) is as essential to the modern economy as water is to human society. Furthering the analogy, participants were asked to imagine if the United States had to import its water from China, which framed the importance for the day's discussion about advanced computing, infrastructure, manufacturing and the digital economy.

Digital technologies, unlike water, will not just fall out of the sky and need to be sourced and developed in the future with deliberate, collaborative action in the innovation ecosystem.

Throughout the day, participants had also repeatedly noted with concern the fact that a typical student's introduction to advanced computing often takes place late in their academic career. A strong recommendation for future PPP models emerging from the day's conversation was to "prime the pump" (aligned to the digital water analogy) for students by engaging them with the material at a younger age. Any stakeholder with access to advanced computing resources—industry, public sector or universities—must inspire a new generation to think of ways to use these resources creatively as they develop academically and professionally. The incentive structure in universities should also be adjusted accordingly to facilitate better engagement with industry, including how academics are evaluated and published.

"We should focus on 'priming the pump' to help with university-industry collaboration."

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

Enthusiastic participants agreed to share additional thoughts on these PPP models through virtual working groups to refine and continue to discuss the proposed PPP models in advance of the next dialogue. In addition to continuing to engage BUILD participants, the Council will also share and solicit feedback on the BUILD Series, developing actionable, new-to-the-world PPP models with its longstanding Technology Leadership and Strategy Initiative (TLSI), as well as the Commissioners of its new flagship initiative, the National Commission on Innovation and Competitiveness Frontiers.

The Council will conclude the BUILD for Advanced Computing Series on May 14, 2019, together with Chancellor James B. Milliken of The University of Texas System in Austin, TX. The University of Texas System is a complementary partner for the next dialogue for its long-standing efforts to promote the development of advanced computing resources and partnerships through its facilities, such as the Texas Advanced Computing Center.

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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