House Committee on Science, Space, and Technology

Research and Technology Subcommittee

"National Science Foundation:

Advancing Research for the Future of U.S. Innovation Part II"

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Chairwoman Stevens, Ranking Member Waltz, and members of the Subcommittee, thank you for inviting me to testify today about how Intel partners with the National Science Foundation (NSF) and to provide comments on the NSF for the Future Act.

I am the Director of University Research and Collaboration at Intel Labs, which is a division of Intel Corporation dedicated to research and development (R&D). In this role I lead a team of forward-thinking technologists that are defining the next generation of computing and communications. We select, fund, and manage critical large and medium scale research centers at leading universities world-wide and ensure research results are translated into seed ideas that lead to transformative innovation at Intel. I also serve as Intel's liaison to the NSF and as a member of the Advisory Committee to the NSF Computer & Information Science & Engineering (CISE) Directorate.

I have spent my career ensuring that Intel can deliver world-changing technologies centered on enriching the lives of every person on earth. I joined Intel over twenty years ago after earning my Chemical Engineering Degree in Costa Rica, where I was born. I moved to the United States to pursue a master's degree in Materials Science and Engineering at Arizona State University, and I currently reside in Oregon where Intel's major R&D facilities are located.

I am delighted to support the NSF for the Future Act, which would comprehensively reauthorize the NSF and set new policy direction to further enable U.S. innovation. Particular points of interest in the bill for Intel are the creation of a new Directorate for Science and Engineering Solutions; a sustainable increase in authorizations of appropriations; support of students, teachers, and broadening participation of minorities in STEM; and provisions to develop and widely disseminate criteria for trusted open data and software repositories.

I recommend that the bill further enable partnerships with private industry by calling for broader consortia, scaling the Convergence Accelerator, and prioritizing funding for major research equipment and facilities construction focused on semiconductor manufacturing. Intel has endorsed positive steps taken by the Administration and Congress to promote U.S. innovation leadership and to protect the integrity of U.S. supply chains for critical technology like semiconductors. The NSF for the Future Act builds on that progress, and I recommend that the bill provide further policy direction spelling out NSF's role in the National Semiconductor Technology Center (NSTC) required under the recently enacted CHIPS for America Act.

Background

Intel Corporation is the world's largest semiconductor manufacturer,[1] employing over 110,000 people globally and approximately 52,000 in the United States. Intel is headquartered in Santa Clara, CA and has manufacturing sites in Arizona, Oregon, and New Mexico and major R&D facilities in Oregon. Intel is one of the last U.S. integrated device manufacturers (IDM), which means Intel owns production over the conception, design, manufacturing, and delivery of most of our products. As a result, Intel is projected to invest $33 billion in capital expenditures and $27 billion in R&D from 2019-2021, the majority of which is conducted here in the United States.[2]

In the United States, private sector companies including Intel account for 73 percent of the total $548 billion U.S. investment in R&D,[3] and Intel ranks sixth among publicly-traded U.S. companies in its individual R&D investment.[4] In 2019, Intel directly contributed almost $26 billion to U.S. Gross Domestic Product (GDP).[5]

Each job at Intel is estimated to support 13 other jobs elsewhere, meaning Intel directly or indirectly supports more than 700,000 full-time and part-time jobs in the United States.[6] Our workforce is highly educated with approximately 90% of people working in technical roles (STEM related professions). We employ many disciplines of technical experts including engineers, chemists, physicists, and mathematicians. In the United States Intel regularly hires graduates with associate degrees, baccalaureate, master's and PhD's. In recent years on average Intel has hired over 150 students graduating from PhD programs, a significant proportion of the graduates in targeted fields across the country.

Intel is one of only three leading edge semiconductor manufacturers in the world and the only one in the United States. The semiconductor products that Intel manufactures provide the foundations for transformational technologies and innovations ranging from personal computing, cloud computing, artificial intelligence (AI), Internet of Things (IoT), 5G, autonomous vehicles, quantum computing, to high-performance-compute solutions, that advance humanity's understanding of, and response to, society's most pressing challenges.

Last month, Intel announced plans to invest $20 billion in the construction of two new fabrication facilities in Arizona and to become a major provider of semiconductor foundry services in the United States.[7] This announcement also included a new research partnership with IBM focused on creating next–generation logic and packaging technologies. Just this week, we also announced a new $3.5 billion investment in our New Mexico facility for the manufacturing

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[1] See IBISWorld Industry Report 33441a, "Semiconductor and Circuit Manufacturing in the US," June 2020.
[2] Intel's Impacts on the U.S. Economy, see https://www.intel.com/content/www/us/en/newsroom/news/us-economic-impact-study.html#gs.0juavq.
[3] National Science Board, Science and Engineering Indicators 2020, see https://ncses.nsf.gov/pubs/nsb20201/u-s-r-d-performance-and-funding.
[4] Intel's Impacts on the U.S. Economy, see https://www.intel.com/content/www/us/en/newsroom/news/us-economic-impact-study.html#gs.0juavq.
[5] Id.
[6] Id.
[7] See https://www.intel.com/content/www/us/en/newsroom/news/idm-manufacturing-innovation-product-leadership.html#gs.zog0za.

of advanced semiconductor packaging technologies.[8] These recent announcements demonstrate Intel's ongoing commitment to leadership investments in R&D and capital expenditures in the United States, investments that enhance U.S. technological leadership and ultimately U.S. national and economic security.

Intel Labs and Components Research

Intel Corporation has two research hub organizations: Intel Labs and Components Research. Intel Labs is focused on advancing technology and design for our products, while Components Research conducts R&D for our manufacturing division. Both organizations are actively collaborating with academic research teams and government agencies. These research teams seek answers, solve problems, and scale solutions. Intel's mission is to engineer solutions to address society's greatest challenges, providing our customers with reliable, cloud to edge computing, inspired by Moore's Law. Our research and development teams support this mission by working together in interdisciplinary research and by partnering with prominent university science and technology centers. Our teams of engineers, physicists, chemists, anthropologists, and psychologists, including more than 600 PhDs, bring a unique cross-section of expertise to our innovation, supporting Intel's purpose, to create world-changing technology that enriches the lives of every person on earth.

Figure 1: Intel's Research organizations

Our expertise is as deep as it is diverse. With 2,500+ patents in the past five years alone, our team of specialists is leading transformative innovation across the most nascent areas of technology. We have led contributed to nearly every major technical standard for hardware interoperability and wireless communications –from USB to Wifi, and from Bluetooth to 5G— widely adopted across the industry and enabling collaboration to unlock innovation at scale.

Research Areas

Intel's research organizations are exploring advancements to Moore's Law, testing novel materials and devices beyond the traditional complementary metal–oxide–semiconductor

[8] See https://www.intel.com/content/www/us/en/newsroom/news/new-mexico-manufacturing.html#gs.0i5sdw.

(CMOS), software and computing system-level architecture, microarchitecture, security, communications, sensing, and novel integration of these technologies.

Figure 2: Intel's key research areas

Some specific examples of technology innovations being explored include:

- Quantum Computing and its potential to tackle problems that conventional computers cannot handle today;
- Neuromorphic Computing, exploration into a new computing architecture that mimics how the brain functions by operating based on feedback from the environment at lower computer power than classical architectures; and
- Many other nascent technologies driving the future of innovations in areas focused on cloud to edge computing.

Intel is working relentlessly to unleash the potential of data, leading to more capable and efficient networks, and pervasive AI across smart devices while improving cybersecurity and taking actions to reduce our carbon footprint. Moore's Law set the pace for the digital revolution and continues to inspire us today to help solve the most pressing societal challenges.

Public-Private Partnerships

Intel research teams work with and sponsor leading researchers, including prominent university science and technology centers, through our extensive network of academic partners consisting of more than 2,500 academic researchers at over 200 universities including to tier research institutions, Historically Black Colleges and Universities (HBCUs) and other minority serving institutions. Collaboration with leading academics is essential to companies like Intel because we can learn from people who are free to take immense risk in their innovative approaches, are constantly exploring the boundaries of the unknown, and are cultivating a new generation of curiosity driven research and creativity. Intel collaborates with academics through direct grants, as a member company to industry affiliate programs created by universities, in other public-private engagements, and in consortia as mentioned above. We collaborate with faculty and students exploring the frontiers in all fields required to make new compute and communications technologies possible. We work across computer science, chemistry, physics, mathematics, and all the engineering fields to deliver new technologies that enrich our lives.

Our collaborative research network is built in part by partnering with federal agencies including the National Science Foundation (NSF), National Institute of Standards and Technology (NIST), Department of Energy (DOE), and Defense Advanced Research Projects Agency (DARPA). It is important to Intel to partner with government agencies because they bring an unparalleled scale and diversity of research reach, as well as the strict adherence to principles of unbiased exploration and fairness. These partnerships are built through direct engagements with the agencies and also through non-profit consortia. Together we are doing research that is transforming how machines think, learn, and adapt and how we compute, secure, share, and communicate the data that fuels our digital economy.

National Science Foundation Collaborations

Intel's partnership with the NSF extends back decades as cofounders of the Semiconductor Research Corporation (SRC). SRC is the world's leading non-profit, industry-government-academia microelectronics research consortium, funding academic research tasks selected and directed by industry and government members. SRC is made up of over 20 premier semiconductor companies, three government agencies, and over 100 universities. SRC manages three programs with a combined 55 research topics and over 500 research projects carried out by over 1,200 SRC-sponsored students. SRC and NSF have a long history of delivering talent and technology to their industry partners across these programs. For example, as part of the SRC STARnet program, Intel transferred technology ideas that have led to breakthroughs in two-dimensional materials and energy efficient devices based on these materials.

In recent years Intel's relationship with the NSF has expanded beyond the SRC consortium into bilateral collaborations directly with NSF through Memoranda of Understanding (MOU). We have been collaborating on specific programs that are funded jointly and have generated technology breakthroughs and fueled innovation in the market. The total funds donated and committed by Intel for these programs is over $40 million, which are leveraged for a total over $150 million including NSF and other members.

In-Kind Contributions

Intel's collaborations with NSF go beyond just providing financial support to academics. We also provide in-kind contributions, like the latest industrial technologies and products, we share use-inspired challenges and bring examples from everyday life to students and faculty. Some of our in-kind contributions include:

- Ongoing contributions of time, expertise and guidance from Intel technical leaders.
- Encouraging faculty and students to meet regularly with Intel technologists to brainstorm on problems, discuss solutions and provide two-way mentorships while pursuing fundamental scientific understanding.
- Hosting students at Intel in short-term internships and invite faculty to present lectures to our broad engineering staffs.
- Establishing a board of advisors for every project comprised of senior researchers, technologists, and business executives from Intel, and in some cases, experts from other companies or senior/retired faculty to provide guidance to the research teams.

- Providing access to our computing cloud infrastructure, where students and faculty can test new products and experiment with early research prototypes.
- Offering Intel Foundry Services as part of our University Shuttle Program, which provides the opportunity for students to get hands-on experience using industrial level design tools and leading process technology for research that yields a silicon prototype

The following is a list of recent and upcoming NSF-Intel programs:

- AI Institute for Optimization (Summer 2021-2025) brings together researchers in constraint satisfaction and search, machine learning, operations research, theoretical computer science, and related fields (such as automated design, signal processing, circuits and systems, etc.) to develop powerful new tools for solving previously "impossible" large-scale problems in planning, resource allocation, strategic reasoning, network and system design and optimization, hardware and software design and verification, and general combinatorial optimization and search.
- Machine Learning for Wireless Networking Systems (MLWiNS) (2020-2022) seeks to accelerate fundamental, broad-based research on wireless-specific machine learning (ML) techniques, towards a new wireless system and architecture design, which can dynamically access shared spectrum, efficiently operate with limited radio and network resources, and scale to address the diverse and stringent quality-of-service requirements of future wireless applications.
- Foundational Microarchitecture (FoMR) (2018-2022) seeks microarchitecture technique innovations beyond simplistic, incremental scaling of existing microarchitectural structures.
- Computer Assisted Programming for Heterogeneous Architectures (CAPA) (2017-2021) aims to address the problem of effective software development for diverse hardware architectures through research that will lead to a significant, measurable leap in software development productivity by partially or fully automating software development tasks that are currently performed by humans.
- Information-Centric Networking Wireless Edge Networks (ICN-WEN) (2017-2020) studied unique data network architectures featuring an information plane using an Information-Centric Networking (ICN) approach and addressing discovery, movement, delivery, management, and protection of information within a network, along with the abstraction of an underlying communication plane, creating opportunities for new efficiencies and optimizations across communications technologies that could also address latency and scale requirements.
- Visual and Experiential Computing (VEC) (2015-2019) fostered novel, transformative, multidisciplinary approaches that promote research in VEC technologies.
- Cyber-Physical Systems Security and Privacy (CPS) (2015-2019) aimed to ensure the security of current and emerging cyber-physical systems, taking into consideration the unique challenges present in this environment relative to other domains with cybersecurity concerns.

In addition, last week NSF announced an exciting new initiative in partnership with NIST, DOD, Intel Corporation, and eight other private companies (Apple, Ericsson, IBM, Google, Qualcomm, Nokia Bell Labs, Microsoft, and VMware) entitled "Resilient and Intelligent Next-Generation Systems (RINGS)." This program, which is the first to include such a significant number of industry partners, will accelerate research in areas that will improve the resiliency of emerging Next Generation (NextG) wireless and mobile communication, networking, sensing, and computing systems. With a total public-private investment of $40 million, NSF anticipates making approximately 40 awards.

Intel also participates in NSF's new Convergence Accelerator program, which was launched in 2019 to fund multi-disciplinary research to address two of the agency's ten "Big Ideas" (Harnessing the Data Revolution and the Future of Work) using a unique partnership model with industry, foundations, government, and non-profits. Under this model, Intel is for the first time engaged directly with academics and funded by NSF. As part of the Convergence Accelerator's 2020 Cohort, NSF selected 29 different teams, including one focused in Neuroscience, Machine Learning and Beyond led by academics from Princeton University, Yale University, and Intel. The progress made by this team in Phase I of the program is showing promising results and the team is looking forward to submitting a proposal for Phase II.

Intel Capital

In addition, through our company's Intel Capital division, we invest in leading disruptors and aid entrepreneurs to build companies that grow and penetrate new markets. Intel has facilitated the transition of research into production technology by in multiple cases, working initially with professors on research funded by NSF-Intel programs, and then supporting the launch of an associated company with an investment from Intel Capital. One example is the start-up Gojoya built on technology developed by University of California San Diego (UCSD) academics as part of the NSF-Intel VEC program. Another funded company that was seeded from NSF-SRC research efforts is CubeWorks, founded in 2013 as a project of the Michigan Micro Mote (M3) initiative from the University of Michigan. The goal of CubeWorks is to deliver a true "smart dust" to open up the next generation of computing paradigm, accelerating massive-scale realization of Internet of Things.

National GEM Consortium

One consortia I would like to highlight is The National GEM Consortium, which is also supported by the NSF. The program is fundamental to Intel's strategy to increase diversity in STEM workforce. Through it we can provide much needed financial support to minority students that want to pursue a graduate education. We ensure students in the program are invited to Intel for their required industrial internship, and we provide mentorship through their studies, an element that we believe is critical in retaining these talented students through to graduation. Since 1991, Intel has sponsored over 400 students through the GEM Consortium, and, in the last five years, Intel has hired over 100 students.

Advancing Research for the Future of U.S. Innovation – the NSF for the Future Act

I appreciate the opportunity to publicly support the NSF for the Future Act, which would comprehensively reauthorize the National Science Foundation and set new policy direction to further enable U.S. innovation. There are important aspects of this bill that would empower the NSF to foster scientific discovery while aiding the acceleration of these new ideas into commercialization.

Directorate for Science and Engineering Solutions: The creation of a new Directorate for Science and Engineering Solutions would be welcomed by industry collaborators such as Intel given the Directorate's focus on societal challenges important to the tech sector and the opportunity to interact with a broader community of scientists. The utilization of multidisciplinary centers and programs, as well as different merit models and mechanisms under this new Directorate, would bring together and allow us to work with representatives from across NSF Directorates, industry, and academia in a way that would expand the types of research questions that can be addressed and improve research outcomes.

Authorizations of Appropriations: I support provisions in the bill to increase overall funding for the Foundation in a sustainable way. These provisions would enable NSF to support more "highly competitive" and "competitive" proposals that go unfunded, as well as to increase current STEM workforce and student programs that would enable technology innovation to flourish in the U.S.

STEM Education: The country today has a significant shortage of STEM workers, at the same time as students from low-income communities' struggle to finance their education and secure their livelihoods. I fully support the efforts proposed to increase funding and scaling for Graduate Research Fellowships, teacher, and post-doc scholarships, and PreK-12 education. Especially important are the allocations of funds to tackle this challenge holistically by focusing on attracting students from two-year colleges and expanding NSF's reach beyond the tier one research institutions. I also support efforts to encourage more partnership between top tier research institutions, HBCUs, minority serving institutions, and tribal institutions. I would be eager to collaborate with such a network of institutions and with the diverse community of students such a network would bring together.

Intel is leading the way in these areas of STEM education. In 2020 the Maricopa Community College District and Intel announced the launch of the first AI associate degree program in the United States.[9] To date we have scaled this program to almost 20 colleges and we expect by this summer there will be 65 instructors trained. A program such us this could be augmented by the NSF in a way that would reach far beyond its current footprint in adoption across the nation.

Research Reproducibility and Replicability: This section of the bill would satisfy historical requests from many in academia. The provisions to develop and widely disseminate criteria for trusted open data and software repositories to be used by federally funded researchers and all of its provisions are necessary measures to extract value from the vast ocean of data that is being

[9] See https://newsroom.intel.com/news/intel-launches-first-artificial-intelligence-associate-degree-program/.

generated by ubiquitous computing. I suggest the NSF can stipulate that data and software be machine readable and usable by researchers. The concept of usability and formatting of the data is important to ensure accessibility by standard data processing tools. For software, if its development is funded by the NSF, then it should be released as open source software under a non-viral license (such as Apache, Berkeley Software Distribution (BSD), or MIT) and not with a viral license (such as General Public License (GPL)). It is difficult for industry to engage with software that is unlicensed or licensed with GPL.

Additional Policy Recommendations – the NSF for the Future Act

Intel has identified areas where the NSF for the Future Act could further enable partnerships with private industry and thereby improve commercialization of university research results, as well as further focus on the critical economic and national security priority of increased semiconductor manufacturing and R&D in the United States.

Consortia Eligibility: The bill could encourage more opportunities for private companies to partner with NSF and institutions of higher education by expanding the eligibility criteria for consortia, explicitly allowing private companies to participate and receive funding directly from the NSF. Our successful experience with consortia like the SRC has demonstrated the positive benefits of such a model, and we believe there would be increased interest and engagement with NSF from private industry if these partnership opportunities were formally elevated and more broadly enabled.

Convergence Accelerator: In addition, the bill recognizes the Convergence Accelerator program as a positive example of a funding mechanism and model for the support of translational research and a convening program where industry, academics, nonprofits, and others can collaborate. I would encourage the bill sponsors to formally codify the Convergence Accelerator program and increase its size and scope in a way that would scale it to meet the ideals of the Directorate for Science and Engineering Solutions.

Private Sector Rotations: Today, NSF provides wonderful opportunities for university academics to work in rotational roles at the Foundation, and I have witnessed both the professional and personal growth of these individuals as well as how their rotation has enriched the team at the NSF. Given this success, I would recommend that the new Directorate for Science and Engineering Solutions expand employment rotation opportunities at NSF to other members of the research community, such as employees of private companies, non-profits, and others. This expansion would facilitate improved public-private collaboration and could ultimately serve as another mechanism to increase technology transfer. I also recommend that the legislation direct NSF to incentivize academic institutions to encourage and allow their faculty to take on short-term appointments or part-time assignments in industry, at non-profits, and within consortia. This encouragement could disincentivize the “brain drain” from academia to industry that is so prevalent in the discipline of computer science and others.

Major Research Equipment and Facilities Construction: The bill directs funding totals of approximately $1.6 billion to the Major Research Equipment and Facilities Construction (MREFC) account at NSF. I believe such an account could be used to help support semiconductor equipment and instrumentation, but these funding levels would not be enough to meet the demand of fundamental research for semiconductors and computing technologies. The cost of construction for infrastructure are high, including platforms and testbeds, data management and software tools, and networks and communication platforms for learning and information sharing. Nonetheless, there is an urgent need within the U.S. research community for use of an experimental semiconductor fabrication facility, and the legislation should take steps to explore funding such a need through MREFC or other mechanisms.

National Semiconductor Technology Center: The CHIPS for America Act enacted earlier this year directs the Department of Commerce, with participation from NSF and the private sector, to establish a public-private National Semiconductor Technology Center consortium to conduct research and prototyping of advanced semiconductor technology to improve the economic competitiveness and national security of the domestic semiconductor supply chain.[10] It is critical that the new proposed Directorate and programs conceived under the NSF for the Future Act leverage NSTC infrastructure and workforce development opportunities, establishing a pipeline of both technology solutions and trained domestic engineers and technicians with hands-on development experience from the NSTC. Access to and partnership with the NSTC would enable significant proof of concept demonstrations and technology transfer to domestic manufacturing capability, as well as critical internship opportunities and work assignments for NSF-funded students and the infrastructure required to mature the technology created by NSF research. We look forward to working with Congress and federal agencies including NSF to better understand and to make recommendations about how the NSTC will be implemented. I would further recommend that the NSF for the Future Act sponsors consider adding policy direction in the legislation about the role of the new Directorate and the agency more broadly in supporting and leveraging the NSTC.

CHIPS for America Act: More broadly, Intel supports robust funding from the federal government to implement the other semiconductor manufacturing and R&D programs established under the CHIPS for America Act. This Committee has an important oversight role regarding many of these programs, including NIST's National Advanced Packaging Manufacturing Program and the Microelectronics Research Program, and the National Science and Technology Council Subcommittee on Microelectronics Leadership, and Intel looks forward to working with you to provide our perspective on implementation of these programs going forward.

Thank you for holding this important stakeholder hearing, and I look forward to answering your questions today and working with you to advance U.S. technological leadership.

[10] Public Law No. 116-283, https://www.congress.gov/116/bills/hr6395/BILLS-116hr6395enr.pdf.