U.S. Senate Committee on Commerce, Science, and Transportation

Hearing on

"Developing Next Generation Technology for Innovation"

Written Testimony of Pat Gelsinger

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March 23, 2022

Chair Cantwell, Ranking Member Wicker, and members of the Committee, thank you for inviting me to testify to share my perspective on the importance of advanced semiconductor manufacturing, research and development (R&D), and workforce in the United States, and the urgent need to fund the *CHIPS for America Act* (CHIPS Act). I am the Chief Executive Officer of Intel Corporation, a global leader in semiconductor technology and manufacturing, and the only U.S. semiconductor company with the depth and breadth of intelligent silicon, platform, software, architecture, design, manufacturing, packaging, and scale, as well as innovation and leading-edge manufacturing capabilities here in the United States. There is an urgent need for the federal government to incentivize more private sector investment in the United States to enable a resilient and innovative semiconductor ecosystem, and I thank the Chair and Ranking Member, along with Senators Schumer, Cornyn, and Young, for their support in advancing legislation to fund the CHIPS Act.

Background

Intel Corporation is one of the world's largest semiconductor manufacturers, employing over 120,000 people globally, including over 55,000 in the United States. We are headquartered in Santa Clara, California, and have manufacturing and R&D facilities in Oregon, Arizona, California, New Mexico, Texas, Massachusetts, and – once construction is complete – in Ohio. Intel is the top employer and a major part of the community in every city where we manufacture:

- **In California**, our total annual economic impact is approximately $24.9 billion, based on 2019 data. We have donated nearly $90 million to support California schools and nonprofits and we employ nearly 14,600 full time equivalents (FTEs) as of January 2020.
- **In Oregon**, our total annual economic impact is approximately $19.3 billion, based on 2019 data. We are Oregon's largest corporate employer with nearly 21,000 FTEs as of January 2021, and we've also invested more than $49 billion in capital to support our operations in the state.
- **In Arizona**, our annual economic impact is approximately $8.6 billion, based on 2019 data. We've invested more than $23 billion in capital to support our operations in the state and we employ nearly 12,000 FTEs there as of January 2021.

- **In New Mexico**, our annual economic impact in New Mexico is approximately $1.2 billion, based on 2019 data. We've also invested more than $16.3 billion in capital to support our operations in the state and employ approximately 1,800 FTEs there.
- **In Texas,** as of February 2021, close to 1,800 FTEs support innovations in cloud computing, Internet of Things, 5G connectivity, memory and programmable solutions.
- **In Massachusetts**, as of February 2021, the 900 FTEs at our research and development center are focused on advanced semiconductor technology, embedding intelligence in the cloud, network, edge, and myriad computing devices to transform business and society.

Intel is one of only three semiconductor manufacturers in the world making advanced logic chips and the only one with the majority of its R&D and intellectual property in the United States. As an integrated device manufacturer (IDM), Intel is the only company in the United States that can do both leading-edge design and manufacturing in-house. This capability has been foundational to our success, enabling product optimization, improved economics, and supply chain resilience. The semiconductor products that Intel manufactures provide the foundations for technologies ranging from personal computing, cloud computing, artificial intelligence (AI), Internet of Things (IoT), 5G, autonomous vehicles, quantum computing, to high-performance-computing.

Intel ranks sixth among publicly-traded U.S. companies in its individual R&D investment,[1] investing $18.7 billion in capital expenditures and $15.2 billion in R&D in 2021.[2] Overall, Intel directly contributed almost $26 billion to U.S. Gross Domestic Product (GDP) in 2019, with a total GDP impact to the U.S. economy of $102 billion.

Manufacturing at Intel

Intel is making unprecedented new investments in U.S. semiconductor manufacturing capacity. In the last 12 months alone, we have announced investments of $43.5 billion for the construction of new semiconductor fabrication facilities in Ohio and Arizona, and for the manufacturing of advanced semiconductor packaging technologies in New Mexico.[3] This follows our recently completed $3 billion investment to expand our operations in Oregon.

Our most recent U.S. announcement in Ohio amounts to a $20 billion investment in a new greenfield manufacturing site in Licking County, which will result in two new mega fabs with the first one coming online by the end of 2025. A full build-out could grow to eight mega fabs and $100 billion over the next decade, assuming support from the CHIPS Act. The manufacturing operations at the Ohio site will produce chips with our most advanced transistor technologies. In addition to more than 7,000 construction jobs, the fabs are expected to create 3,000 high-paying, long-term Intel manufacturing and engineering jobs ranging from factory

[1] "Intel's Impacts on the US Economy", Report Issued April 2021, using data for FY 2019, available at https://www.intel.com/content/www/us/en/newsroom/news/us-economic-impact-study.html?wapkw=economic%20impact#gs.tptln6.
[2] Intel Corporation Annual 10-K for Fiscal Year Ending December 25, 2021, available at https://www.intc.com/filings-reports/all-sec-filings/content/0000050863-22-000007/0000050863-22-000007.pdf
[3] See Intel Press Releases available at https://www.intel.com/content/www/us/en/newsroom/news/intelannounces-next-us-site-landmark-investment-ohio.html; https://www.intc.com/news-events/press-releases/detail/1501/intel-breaks-groundon-two-new-leading-edge-chip-factories; https://www.intel.com/content/www/us/en/newsroom/news/new-mexico-manufacturing.html.

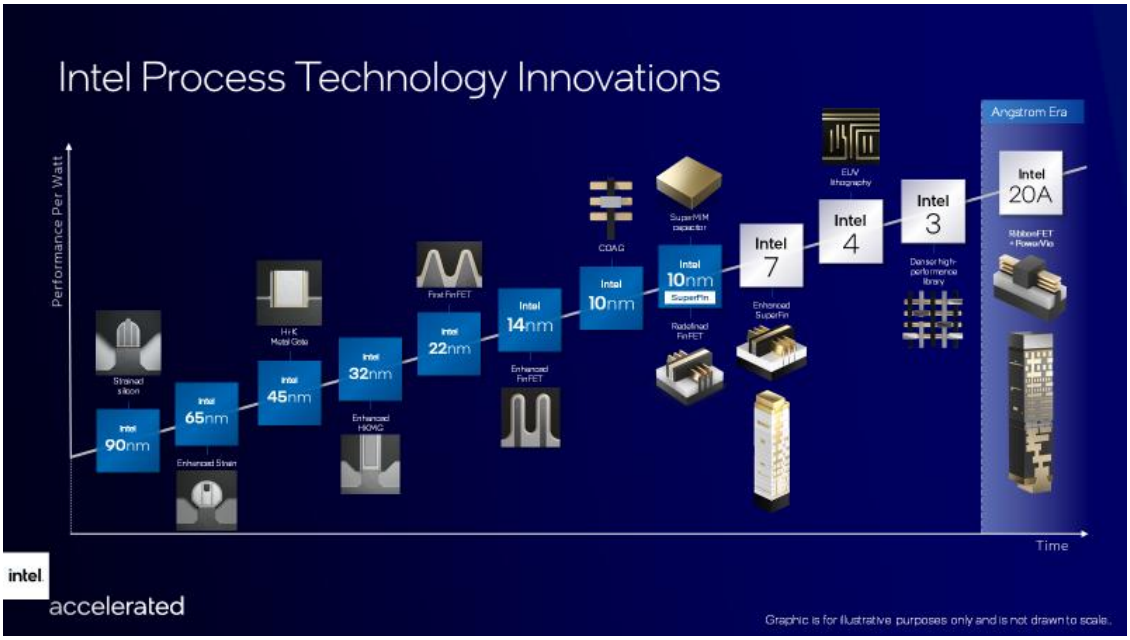
operators and equipment technicians to engineers and business support functions, many of which do not require a 4-year college or advanced degree.

Technology Development at Intel

More than fifty years ago, Intel invented the world's first commercial microprocessor. We have led in process technology for more than four decades until recently, and developed all major logic process innovations that the semiconductor industry uses (i.e., strained silicon, Hi-K metal gate, 3D transistors). Intel is executing a plan to recapture the global leadership in process technology by 2025.

Today, Intel's technology roadmap relies on new levels of innovation, including not only deep transistor-level enhancements, but also innovations all the way up the stack to the interconnect and standard cell level. The company has moved to an accelerated pace of innovation to enable an annual cadence of process improvements. Earlier this year, I unveiled one of the most detailed process technology roadmaps that Intel has ever provided, showcasing a new node naming system and breakthrough technologies including:

- **RibbonFET**, our first new transistor architecture in more than a decade
- **PowerVia**, an industry-first new backside power delivery method
- **High NA EUV**, our plans to adapt next-generation High Numerical Aperture extreme ultraviolet lithography



Technology advances in electronic packaging have supported and sustained Moore's Law silicon scaling and have evolved to become an important enabler of product performance. Intel is a leader in heterogenous integration technology. Our Foveros advanced packaging technology uses 3D stacking to enable logic-on-logic integration, and when combined with our Embedded

Multi-die Interconnect Bridge (EMIB) technologies, allows for the interconnection of different chiplets and tiles with essentially the performance of a single chip.

Intel's Ponte Vecchio, a product targeted for Argonne National Laboratory's exascale Aurora Supercomputer, represents the current state of the art in packaging.

Workforce at Intel

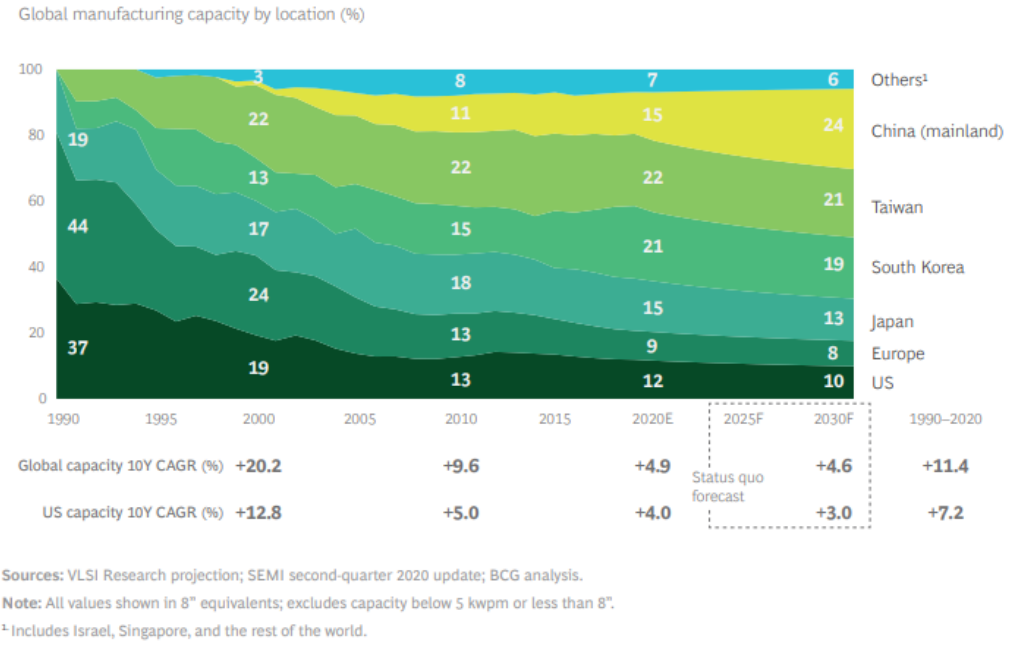
Our industry supports a large and vibrant workforce. Each of the new leading-edge fabs we are building in the United States supports approximately 1,500 permanent Intel jobs, in addition to the many thousands of construction jobs created by these projects. And for each permanent Intel job we create, our operations indirectly support an additional 13 jobs among suppliers and partners in the semiconductor ecosystem. More broadly, the U.S. semiconductor industry directly supports 250,000 jobs, indirectly supports another one million jobs, and supplies digital infrastructure to countless employers across the country.

Last week, Intel announced two new initiatives that together will invest $150 million into semiconductor-related research, education, and workforce development programs in two- and four-year institutions across the country.

- Intel announced a new 10-year, **$100 million national partnership with the National Science Foundation (NSF)**[4] to expand semiconductor-related education and research programs. Intel is committing $50 million to this initiative, with $50 million in matching funds from NSF. Funds will be used to create new curricula for associate and undergraduate degrees, certification programs, and reskill and upskill programs for existing workers, as well as to support faculty training, laboratory equipment, and research supporting semiconductor design and fabrication.
- To support the new Silicon Heartland in Ohio, Intel is also investing **$50 million directly into Ohio institutions** over the next 10 years. This investment will fund various programs, including the *Intel Semiconductor Education and Research Program*

[4] See "Media Alert: Intel Launches Education and Research Initiatives for Ohio, US," Mar 17, 2022, https://www.intel.com/content/www/us/en/newsroom/news/media-alert-intel-launches-education-initiatives.html#gs.ty6ba3

for Ohio, a collaborative, multi-institution program designed to improve semiconductor innovation and provide real-world experience to students.



Two weeks ago, Intel also announced a new "**Quick Start**" accelerated workforce development program with Arizona community colleges to train and retrain workers as semiconductor technicians.[5] These and other initiatives build on the work Intel has been doing for years to promote cutting-edge research and prepare students for the industry, such as with local community colleges to develop and maintain microelectronics technology programs for semiconductor technicians. Through partnerships with NSF, Intel regularly funds education and research programs with colleges and universities across the country. And Intel funds numerous efforts like the **Million Girls Moonshot (MGM)** program[6] to expand outreach to, and participation by, traditionally underrepresented groups, including underrepresented minority groups and women and girls.

State of U.S. Semiconductor Manufacturing

The U.S. share of semiconductor manufacturing capacity has dramatically fallen over the last 30 years. In 1990, the United States manufactured 37 percent of the world's supply of semiconductors but today only produces 12 percent, a share forecasted to decline even further without intervention.[7]

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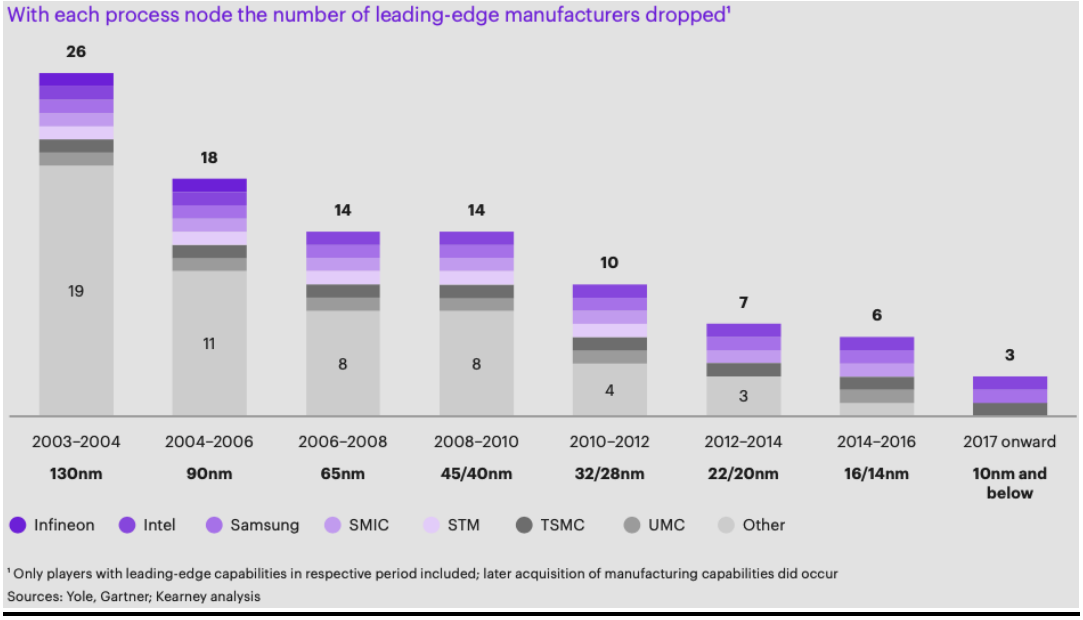
[5] See "Maricopa Maricopa Community Colleges and Intel to Launch New Semiconductor Manufacturing Workforce Development Initiative," March 7, 2022, https://www.intel.com/content/www/us/en/newsroom/news/maricopa-community-colleges-intel-launch-workforce-development-initiative.html#gs.tzsvej

[6] More information at https://milliongirlsmoonshot.org.

[7] See "Government Incentives and US Competitiveness in Semiconductor Manufacturing," by Antonio Varas, Raj Varadarajan, Jimmy Goodrich, and Falan Yinug, September 2020, available at https://www.semiconductors.org/wp-

So how did we get here? The decline in U.S. manufacturing share was driven in part by countries in East Asia investing in this critical technology and in their domestic champions, creating vital chipmaking ecosystems in the process. Those investment policies, combined with lower labor rates, effectively created a 30-50 percent cost disadvantage to manufacture chips in the United States. At the same time, the cost just to build and equip a single manufacturing facility that used to cost just $3 billion a decade ago can now cost more than $10 billion, making government incentives critical to site location decisions. As a result, our industry has concentrated itself in East Asia. Intel constitutes more than half of the advanced logic being manufactured in the United States, and we are working to do more, but our competitors have a significant cost advantage that is increasingly difficult to overcome.

Substantial investments into process technology development are also necessary to master the processes required to operate a leading-edge fab, but integrated circuit scaling is getting more difficult as traditional devices reach their scaling limits. As a result, lithography is now the most important step in fabricating integrated circuits and is also the most expensive in terms of total wafer processing cost. Due to these dramatic increases in manufacturing and technology development expenses, fewer and fewer manufacturers globally can absorb the investments required to develop the latest node sizes (see figure below). Today, only three leading-edge logic manufacturers remain. [8]



Advanced packaging technologies are also undergoing a major transition from primarily connecting small geometry wiring on a die to the looser wiring density on a system board to connecting small geometry wiring between many die inside one package. This 3D Heterogeneous Integration, using novel package technology as its core building block, is

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[8] See Kearney analysis in "Europe's urgent need to invest in a leading-edge semiconductor ecosystem," Nov 2021, https://www.kearney.com/documents/20152/272966470/Europes+urgent+need+to+invest+in+a+leading-edge+semiconductor+ecosystem.pdf

becoming vital to the semiconductor industry as traditional chip scaling slows down. Currently, less than two percent of the capacity for assembly, test and substrate manufacturing is in the United States. With the reported investments of Asian countries coupled with that of Asian private sector companies in 3D packaging, the United States and U.S. based companies are becoming further challenged to maintain their leadership.

Semiconductor Technology R&D in the U.S.

Intel and other semiconductor companies reinvest on average nearly 20 percent of their revenue into R&D, one of the highest percentages of any sector. Forty years ago, federal investment in semiconductor R&D was more than double that of private investment, but today, U.S. private investment is nearly 20 times that of public funding. Intel is committed to continuous investment in semiconductor manufacturing, but the private sector cannot do it alone, and time is not on our side. It takes at least three years to build state-of-the-art manufacturing facilities and five to 10 years for supply chains to move. Federal investment is needed urgently and would unlock tens of billions of dollars in private investment here at home.

A November 2021 paper from the Boston Consulting Group (BCG) identified the two most significant gaps currently facing the United States in establishing those three ingredients: (i) a 30 to 50 percent cost disadvantage with East Asia that U.S. chipmakers face; and (ii) public funding for R&D, which lags both Taiwan and Korea where the most advanced semiconductors are currently manufactured.[9] Not only is technology-specific federal funding related to semiconductors as envisioned in USICA important, but Congress must also continue to encourage companies to invest private funds in U.S. R&D.

Starting in January 2022, businesses are now required to amortize their R&D expenses over several years. Removing this deduction under the Tax Cuts and Jobs Act (TCJA) created the most regressive treatment of R&D investments globally. U.S. investment in research is already relatively flat. This major change will significantly increase the cost to perform R&D in the U.S., while other governments work to substantially increase R&D investment in their respective countries. I applaud the bipartisan work of Senators Hassan, Young, Cortez Masto, and Portman, whose bill, the American Innovation and Jobs Act, would restore this immediate deduction which has existed for nearly seven decades. As Congress works to reconcile the U.S. Innovation and Competition Act and the America COMPETES, we encourage Congress to incentivize R&D investment in the U.S. by fixing this important provision as well.

U.S. Workforce and Workforce Development

As intended, the CHIPS Act would help the United States close the manufacturing share gap by levelling the playing field so companies would be more apt to choose to build their fabs domestically. Those fabs, however, will require significant expansion of talent pipelines. The industry depends on workers across a range of skillsets, including trade workers to build new fabs and packaging facilities; technicians and trade workers to operate and maintain these facilities; and advanced degree STEM graduates for research and development. Due in part to tight labor markets, hiring in each of these areas is already extremely difficult. These

[9] See "Establishing Leadership in Advanced Logic Technology," Raj Varadarajan, Ramiro Palma, and Antonio Varas, Nov 2021, https://web-assets.bcg.com/8d/cf/6a4a4ab34d5f962e1526337ef691/bcg-establishing-leadership-in-advanced-logic-technology-nov-2021-r2.pdf

difficulties will only skyrocket as new fabs come on-line. Unless we do more as a country, workforce availability has the capacity to be the principle limiting factor to a strong U.S.-based semiconductor industry.

Intel has already begun to do its part to significantly expand talent pipelines, but more will certainly need to be done if we want to stay competitive as a nation, and the industry cannot do it alone. Federal investment through the CHIPS Act is an important start, as it would unlock additional private investment to increase domestic manufacturing and further drive the research, education, and workforce development efforts needed to support industry expansion. Additional efforts will also be needed to attract and retain students in STEM fields—particularly at the graduate level and in the sub-fields critical to the industry, such as electrical engineering and computer science. U.S. students do not choose those fields at anywhere near the rate needed to support significant industry expansion. And our outdated immigration system makes it extremely challenging to hire and retain foreign students graduating from U.S. universities in these critical fields. If we are to stay competitive as a country, Congress must work to improve the industry's ability to win the global competition for talent, especially at the highest levels.

Supply Chain Resilience

The global chips shortage has been uniquely impactful among the many supply chain woes the world has experienced since March 2020. For two years now, U.S. companies and consumers have had to navigate a global chip shortage and its rippling effects. Semiconductors are a critical part of every digital device, powering our phones, cars, hospitals, and factory floors. Yet the pandemic brought into sharp relief the state of the semiconductor supply chain as neither stable nor durable. A severe supply-demand imbalance led to idled factory lines, bare shelves, empty car lots, and backorders on goods. The global chip shortage cost the U.S. economy approximately $240 billion last year.

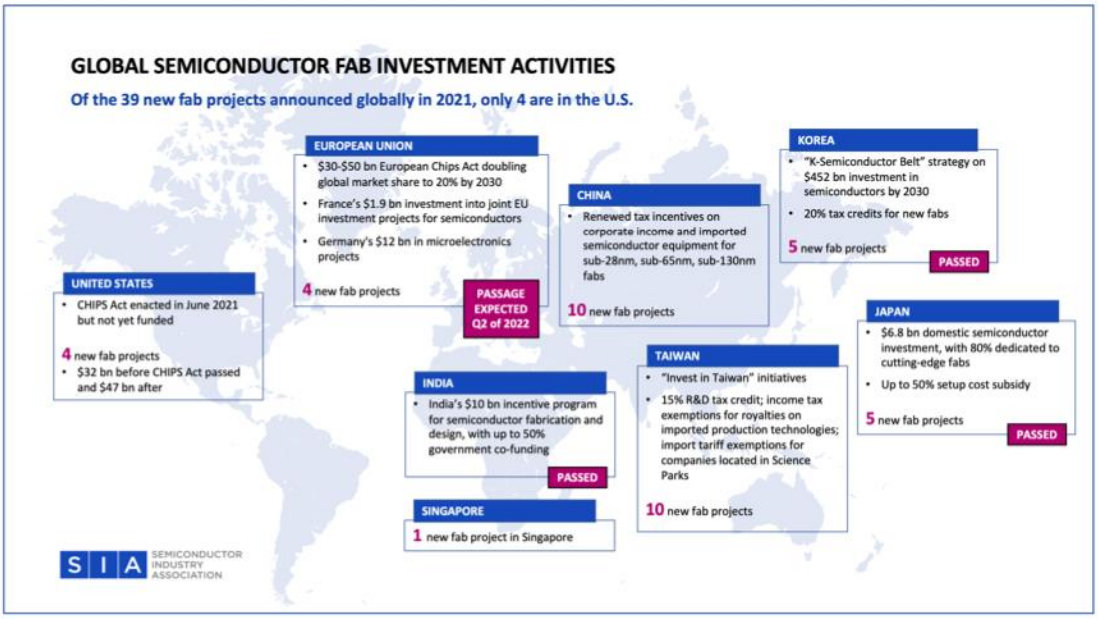
Among the many lessons of the pandemic is that chip shortages can sideline both workers and entire segments of the economy, illustrating the national and economic security risks of falling behind. Our economic security depends on reliable, resilient access to semiconductors— access that requires near-term investment, at scale, in domestic capability and capacity. Given that so much of the semiconductor and technology industry supply chain resides in East Asia, future risks are far greater than the shortages we are experiencing today. The only way to alleviate the current supply-demand imbalance, prevent future shortages, and ensure resilient access to chips is to increase U.S. chip manufacturing capacity.

Intel is committed to helping rebalance the global supply of chips and reduce current dependencies in East Asia. Increasing manufacturing in both the U.S. *and* EU are key to that goal, and consistent with the U.S. and European governments' desires to work together on supply chain issues. The US-EU Trade and Technology Council (TTC) has established a working group on supply chain issues, and at its first formal meeting issued a Statement on

Semiconductor Supply Chains with specific focus areas, including increasing sorely needed investment in both jurisdictions.[10]

Strengthening U.S-EU partnerships like the TTC is critical to help both regions reach their similar semiconductor objectives. Last week, I announced investment plans in the EU (specifically Germany, Ireland, France, Italy, Poland and Spain) of more than $36 billion for semiconductor R&D and manufacturing. These investments will complement the over $43 billion in capital investments we have previously announced in the U.S.

The rest of the world is investing and moving very rapidly. As Congress deliberated how to fund the CHIPS Act over the last year, other countries in Asia and Europe have moved forward with their own new or additional incentive programs, as shown in the graphic below from the Semiconductor Industry Association (SIA). SIA writes, "In 2021 alone, 25 fab construction and expansion projects have been announced among U.S. foreign partners – Europe, South Korea, Japan, Taiwan, and Singapore. In contrast, just 4 have been announced in the United States. Government incentives are enabling foreign competitors to outpace the U.S. in fab construction and investment."[11]



[10] The Statement reads in part: The United States and European Union "reaffirm their willingness to build a partnership on the rebalancing of global supply chains in semiconductors with a view to enhancing their respective security of supply as well as respective capacity to design and produce semiconductors, especially, but not limited to, those with leading-edge capabilities . . . we underline the importance of jointly identifying gaps and vulnerabilities . . . and strengthening our domestic semiconductor ecosystems, from, research, design to manufacturing . . . we intend to focus on reducing existing strategic dependencies[,] especially through a diversification of the supply chain and increased investment." U.S.- EU Trade and Technology Council Inaugural Joint Statement, Annex IV (Pittsburg, PA September 29, 2021); available at https://www.whitehouse.gov/briefing-room/statements-releases/2021/09/29/u-s-eu-trade-and-technology-council-inaugural-joint-statement/.

[11] From "Global Semiconductor Incentives," February 2022, by the Semiconductor Industry Association, https://www.semiconductors.org/wp-content/uploads/2022/02/Global-Semiconductor-Incentives_2-4-2022.pdf

CHIPS Act Implementation Recommendations

The efficient and expeditious implementation of programs under the CHIPS Act, including the financial assistance program for semiconductor manufacturing and R&D facilities ("Grant program"), the National Semiconductor Technology Center (NSTC), and the National Advanced Packaging Manufacturing Program (NAPMP), will be essential to alleviate semiconductor supply constraints more quickly and reverse the erosion of domestic capacity for U.S. semiconductors. Our comments on the Commerce Department's Request for Information, due this Friday, include several recommendations some of which are summarized below.

General Grant Program (Section 9902)

The grant program should prioritize and expedite approval for shovel-worthy projects that have already been announced or are already underway to receive the first round of grants, in order to accelerate the impact of federal funds and see results more quickly.

The federal government should also expedite federal permitting requirements under the National Environmental Policy Act (NEPA) for these projects, which can add years to the approval timeline. Such expediting can be accomplished legislatively or administratively with fast-track approval,[12] or more preferably, through a definitive "categorial exclusion"—at least for facilities already under construction where the environmental impact has been thoroughly examined under state law and is not significant. The Department of Energy's experience with the Advanced Technology Vehicles Manufacturing Incentive Program ("Auto Loan Program") is instructive precedent. Under the Auto Loan Program, DOE provided loans to automobile manufacturers and component suppliers for projects that reequipped, expanded, and established manufacturing facilities in the United States to produce light-duty vehicles. In 2009, DOE applied categorical exclusions to manufacturing facilities that received federal funding under the program after concluding that the activities contemplated were substantially similar to activities covered by the agency's existing categorical exclusions.[13] The U.S. should also look to the fast-track permitting process for environmental and other assessments that the European Commission is asking its member states to implement for first-of-a-kind semiconductor facilities as a best practice.[14]

The grant program should also consider factors in addition to those included in the statute when determining the grant amount for a specific project, such as the project's contribution to American technology leadership and supply chain security; the project's size, broader economic impact, and number and quality of American jobs it creates; more specific national security implications that the project may raise; and the project's ability to sustain itself after federal assistance is used up and operate independently from foreign government influence and overseas technical assistance.

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[12] *See* S. 3541, a bill to include certain computer-related projects in the Federal permitting program under title XLI of the FAST Act, and for other purposes; available at https://www.congress.gov/bill/117th-congress/senate-bill/3451?s=2&r=4.

[13] *See* Letters between Steven Chu, Secretary of Energy, and Nancy Sutley, CEQ Chair (Mar. 19 and Mar. 20, 2009)(relying on Department of Energy Categorical Exclusion B1.31).

[14] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, A Chips Act for Europe, at 17, COM (2022) 45 Final (Brussels 8.2.2022); Proposal for a Regulation of the European Parliament and of the Council, European Commission 2022/0032, establishing a framework of measures for strengthening Europe's semiconductor ecosystem (Chips Act), at 7-8 (Brussels 8.2.2022).

National Semiconductor Technology Center (NSTC)
The Commerce Department, working through the National Institute of Standards and Technology (NIST), should establish a nationwide network of facilities at U.S. companies, leveraging access to existing infrastructure to save the federal government cost and time. This network of centers or hubs should focus on conducting research for precompetitive "breakthrough challenges" that align industry around revolutionary goals more than five years out and ultimately can result in competitive products that can be manufactured at high volume in the United States. Intel proposes establishing one such center dedicated to providing access to advanced lithography tools and equipment, a critically important area to enable future process technology advancements.

The federal government should allow operation of the NSTC consortium to be led by a neutral non-profit entity with the guidance of a technical advisory committee, and should fund NSTC with the private sector jointly, in a manner that enables its long-term sustainment. NSTC should also support precompetitive prototyping to lower the barrier of entry for start-ups. Opportunities also exist for scaling semiconductor education and workforce initiatives at the university level through partnership and access to the NSTC.

National Advanced Packaging Manufacturing Program (NAPMP)
The NAPMP should, with the guidance of a technical advisory body, focus on research projects such as those related to product capability, environmental footprint reduction, and supply chain resilience to advance domestic manufacturing. As part of the NAPMP, NIST should establish an Advanced Packaging Manufacturing Center to research new package and assembly/test technologies and manufacturing methods, and to demonstrate a fully integrated manufacturable process. Such a center could incorporate satellite building block projects to perform R&D on core technology elements and could facilitate heterogenous integration research in support of the NSTC along with accelerating innovation in packaging and test technology. It will be beneficial to have technical alignment between the NAPMP and the NSTC to ensure synergies on project prioritization and focus for pre-competitive R&D.

Conclusion

Time is of the essence: American businesses in every sector across the economy are facing a semiconductor shortage, and the only way to alleviate the current supply-demand imbalance long term is to increase manufacturing capacity by funding and implementing the CHIPS Act. Polls consistently show Americans understand the importance of the chipmaking industry to the U.S. economy and national security, and widespread support for Congressional action to allocate federal funding for the industry.[15]

We hope Congress can soon find a path forward to reconcile the U.S. Innovation and Competition Act and the America COMPETES Act to fund the urgently needed CHIPS Act programs it authorized over a year ago. The rest of the world is moving forward, and the United States must move forward quickly as well.

[15] Survey showed 90 percent of Americans either strongly or somewhat support the proposal to allocate funding for domestic chipmaking. Research was conducted by ENGINE INSIGHTS omnibus survey among U.S. adults over 18 based on a sample of 1,008 during November 17-19, 2021.

Intel is fully committed to diversifying the semiconductor supply chain. By the end of the decade we hope to see the U.S. manufacturing share grow from 12 percent to 30 percent, and the European manufacturing share grow from 9 percent to 20 percent. The CHIPS Act is the critical first step to make that happen.

This Committee will play an important role in overseeing the CHIPS Act programs, and we look forward to working with you and the Department of Commerce to provide our perspective on implementation of these programs going forward. Thank you for holding this important stakeholder hearing today; I look forward to answering your questions and working with you to advance U.S. semiconductor manufacturing and R&D.