ITIF | INFORMATION TECHNOLOGY & INNOVATION FOUNDATION

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Department of Commerce
1401 Constitution Ave. NW
Washington, DC 20230

Dear Colleague:

The Information Technology and Innovation Foundation (ITIF) is pleased to provide comments in response to the Department of Commerce's (DoC) request for information (RFI) on Docket Number: 220119-0024, "Incentives, Infrastructure, and Research and Development Needs to Support a Strong Domestic Semiconductor Industry."

Sincerely,

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America's experience with the semiconductor industry, just as with any other advanced-technology industry, illustrates that leadership is never assured: indeed, the United States has created and led, lost, and regained global leadership in semiconductor innovation and production, only to see it, in some dimensions, increasingly slip away again.[1] To that end, ITIF applauds both the Biden administration and U.S. Congress for articulating and advancing the Creating Helpful Incentives to Produce Semiconductors ("CHIPS") for America Act, which has been passed out of the Senate and House in largely similar form in their respective U.S. Innovation and Competition Act (USICA) and America COMEPTES Act.[2] The legislation recognizes that concrete policy action is needed if America is to maintain its world-leading position in semiconductor chip design and restore a world-leading position in semiconductor manufacturing and logic chip innovation. The programs and incentives envisioned in the legislation will need to be deftly and expediently administered by a multitude of federal agencies, especially the Department of Commerce.

This submission provides input to the DoC RFI with regard to semiconductor research and development (R&D), incentives to stimulate domestic semiconductor manufacturing, talent pipelines, policies that can stimulate greater domestic demand for semiconductors, and enhancing semiconductor supply chain resilience. The submission draws heavily from several recent ITIF reports, including "An Allied Approach to Semiconductor Leadership" (July 2020), "Moore's Law Under Attack: The Impact of China's Policies on Global Semiconductor Innovation" (February 2021), and "Going, Going, Gone? To Stay Competitive in Biopharmaceuticals, America Must Learn From Its Semiconductor Mistakes" (November 2021).

RESEARCH AND DEVELOPMENT

The U.S. government needs to significantly increase its investments in semiconductor-related R&D. In 2019, the U.S. federal government invested just $1.7 billion in core, semiconductor-specific R&D (along with an additional $4.3 billion in research in semiconductor-related fields). And whereas 40 years ago federal funding for semiconductor R&D was more than double the level of private-sector funding, in 2019, U.S. private sector investment of about $40 billion in semiconductor R&D was 23 times greater than the federal government's level of investment.[3] To this end, ITIF supports the CHIPS Act's call for $10.5 billion worth of commercially oriented semiconductor R&D investment over the next five years. This would be augmented by $2 billion for a CHIPS for America Defense Fund, at $400 million over five years, that would provide support for R&D, testing and evaluation, and workforce development in coordination with the private sector, universities, and other federal agencies to support the needs of the Department of Defense and the intelligence community.

However, even with regard to the aforementioned $1.7 billion in then-annual federal R&D investment in semiconductor-industry R&D, much of this has been agency program manager-led; America's semiconductor R&D investments could achieve much greater impact if programs and initiatives were more effectively coordinated across the federal government, which should be a focus of new R&D monies coming out of the USICA/COMPETES legislation. Beyond increasing R&D funding, the impact and commercialization potential of these types of consortia could be increased with more-flexible federal contracting guidelines, such as a relaxation of Federal Acquisition Regulations or the ability to make greater use of other transactional authority vehicles (as the

Semiconductor Research Corporation and DARPA have used for over 20 years, but which could be used more broadly).[4]

A significant segment of increased federal R&D funding for semiconductors should be directed to collaborative, pre-competitive R&D activities. Collaborative, pre-competitive research and the development of coordinated industry technology roadmaps have long been a hallmark of the semiconductor innovation process, especially given the expense and scale required to successfully innovate in the sector.[5] In 1987 the U.S. industry and government collaborated to establish SEMATECH, a public-private research consortium that sought to help improve U.S. industry's technological position by developing advanced manufacturing technology, with a particular focus on increasing the speed and quality of chip production systems.[6] According to the National Academy of Sciences, "SEMATECH was widely perceived by industry to have had a significant impact on U.S. semiconductor manufacturing performance in the 1990s."[7] The United States needs to pursue a similar model today.

To this end, ITIF supports USICA's call for $2 billion in FY 2022 to fund creation of a National Semiconductor Technology Consortium (NSTC). The NSTC would serve as a hub for conducting advanced semiconductor research and prototyping that strengthens the domestic ecosystem, bringing together industry, government, national labs, and academia around a common roadmap to drive innovations in semiconductors and develop the semiconductor workforce.[8] NSTC could fill the role SEMATECH once fulfilled in the U.S. semiconductor innovation ecosystem.

With regard to organization of the NSTC, the broad outline of America's Manufacturing USA Network of Institutes should provide a guide. NSTC participants should co-invest in a public-private partnership with the government and membership should be open to a range of semiconductor firms of varying sizes, including small-medium-sized enterprises (SMEs), with scaled membership tiers available to fit the needs and contribution capacity of firms of various sizes. One of the more important functions of the NSTC should be to serve as an industrial commons for the U.S. semiconductor industry, and especially to provide a platform for start-up chip design firms to test their new chipsets. One of the challenges U.S. start-up design firms have faced is that a lack of fab capacity in the United States has meant these types of firms have had difficulty in getting small-batch prototyping work done at larger fabs usually expecting production runs in the millions. The NSTC can serve a very important testbed/prototyping role for the U.S. semiconductor ecosystem.

Another focus of semiconductor-related R&D should be reanimating U.S. leadership in advanced packaging. Assembly, test, and packaging (ATP) represents the final step in the semiconductor-manufacturing process, but the packaging process—traditionally viewed as labor-intense and lower-value-added—has been almost entirely offshored from the United States, now centered in Southeast Asian nations. But as semiconductor designs have become more complex and increasingly two- or three-dimensional in nature, packaging has become more intimately connected with both the design and fabrication aspects of semiconductor production, and so leadership in this area matters as well. The ascension of multi-component (MCO) semiconductors, which combine one or more integrated circuits with one or more discrete semiconductor devices (such as a sensor, oscillator, or resonator) into a single integrated package, illustrate the importance of leadership in modern packaging techniques. To that end, IITF supports USICA's call for a $2.5 billion investment in FY 22 to create an U.S. advanced packaging institute.

Beyond R&D programs to support the needs of the industry today, an equally significant share of funding must go into transformative leapfrog technologies to reach the next-generation of semiconductor design and production Here, it's imperative that the R&D considers chip design and fabrication simultaneously, because there's such intimate linkages between semiconductor process and product innovation, and R&D without manufacturing knowledge is not as useful as the two combined.

Indeed, America's semiconductor R&D programs should be exploring potentially transformative, longer-term research. For instance, the 2017 President's Council of Advisors on Science and Technology (PCAST) report on "Ensuring Long-term U.S. Leadership in Semiconductors" called for identifying "carefully selected ambitious challenges or 'moonshots,' as focal points for industry, government, and academic efforts to drive computing and semiconductor innovation forward together."[9] As the report explains:

> Our recommended approach to designing the moonshots is driven by the fact that the future of semiconductors and computing lies in innovating along multiple dimensions: new ways of performing calculations (such as non-von Neumann and approximate computing), utilization of materials other than silicon (such as carbon nanotubes and DNA for computation and storage), and novel approaches to integrating semiconductors into the devices we use (such as embedding into fabrics and the Internet of Things, or IoT).[10]

Possible semiconductor-sector moonshots that PCAST identified included:

- Developing affordable desktop semiconductor fabrication capabilities that could take the place of a billion-dollar fabrication facility and allow the production of small batches of structures;
- Using 3D printing at the nanoscale to connect "hard" electronic materials with "soft" biological materials, which could be the foundation of a zero-day bio-threat detection network; or
- A commercial, gate-based quantum computer to work on large-scale problems.

The first moonshot objective, in particular, around increasing semiconductor R&D efficiency, in both design and manufacturing processes, could be ripe for NSTC consideration. For instance, a representative of one semiconductor company noted that today it can take as many as 2,000 people up to two years to develop a new-to-the-world semiconductor design and that industry should endeavor to collectively cut both components by a factor of at least 10.

The PCAST report suggested that semiconductor-sector moonshots should be designed with a 10-year time horizon, focus on reducing design costs, take an applications-driven approach, and compensate for areas of weak industry investment. As the PCAST report noted, "Government will also almost certainly need to back these efforts with significant, catalytic funding to overcome the risks associated with radical innovation."[11] The PCAST report suggested several "best-practice models" that could advance progress toward achieving the moonshots, including the use of incentive prizes, creating an industry-led venture capital consortium, establishing a Manufacturing USA Institute for semiconductor moonshots, and expanding U.S. government-sponsored industry-academic research fellowships in the field.[12]

While all these are positive proposals and should be pursued, given the significant investments required to pursue these worthy moonshots, the U.S. government should consider inviting partners from like-minded nations to co-invest in the moonshots, with resulting IP or technical discoveries shared at levels proportionate to mutual investment. The same principle should apply to the NSTC: semiconductor firms from like-minded nations should be welcomed to participate; however, only so long as their nations afford eligibility to U.S. semiconductor enterprises in their similar programs.

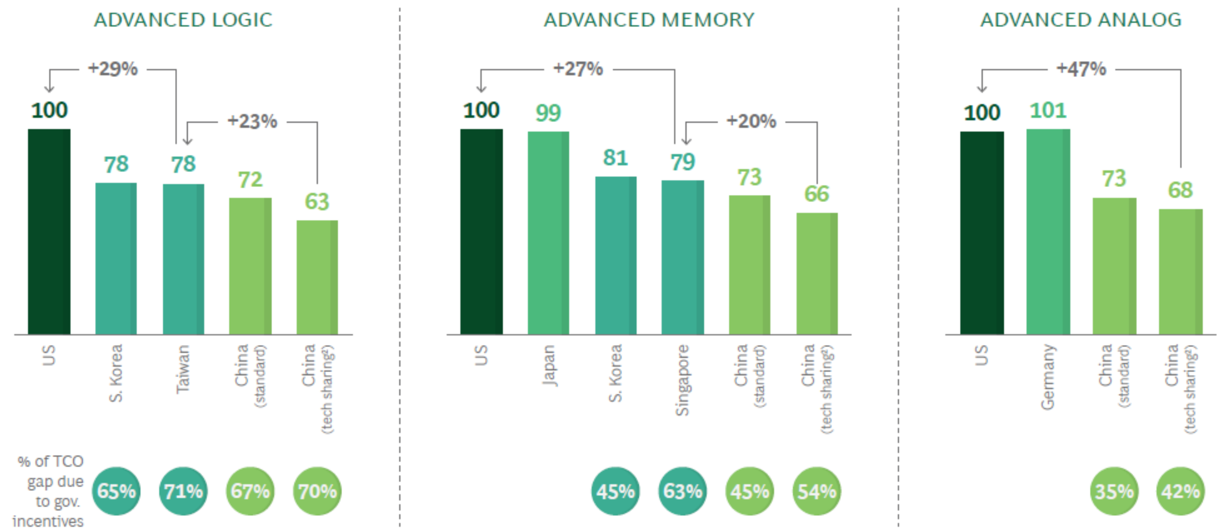
INCENTIVES TO STIMULATE DOMESTIC SEMICONDUCTOR MANUFACTURING

The United States' share of global semiconductor manufacturing activity has fallen by 70 percent over the past three decades, falling from a 37 percent share in 1990 to just a 12 percent share by 2021.[13] At current trends, with just 6 percent of new global semiconductor capacity development expected to be located in the United States over this decade, absent effective policy intervention, the U.S. share of global semiconductor manufacturing capacity is expected to fall to 10 percent by 2030. Moreover, the current reality is that the vast majority of the world's most sophisticated semiconductor logic chips, those at the sub 10 nm process node level or below, are manufactured in Asia, where Taiwan held a 92 percent share and South Korea the remaining 8 percent, as of 2019.[14]

One reason the United States has lagged in launching new semiconductor fabs over the past three decades is that other nations have much more aggressively offered incentive packages to attract that manufacturing activity.[15] In many of these countries, such as Japan, Israel, Singapore, South Korea, and Taiwan, such incentive packages are offered at the national Ministry of Economy level to attract globally mobile semiconductor investment (in China such packages are offered at both the national, provincial, and regional levels). For example, South Korea offers a program of 40 to 50 percent tax credits for chip R&D and 10 to 20 percent tax credits for facility investments, as well as low-cost loans therefore.[16]

Put simply, other countries are willing to incentivize the building of semiconductor fabs, whereas the United States is largely not. That explains much of the U.S. decline. Many countries help companies defray the high costs of building a fab, with incentives that reduce up-front capital expenditures on land, construction, and equipment and that can also extend to recurrent operating expenses such as utilities and labor. One stud estimated that foreign government incentives may offset from 15 to 40 percent of the gross total cost of ownership (pre-incentives) of a new fab, depending on the country.[17] The 10-year total cost of ownership (TCO) of U.S.-based semiconductor fabs is 25 to 50 percent higher than in other locations, with government incentives accounting for 40 to 70 percent of the U.S. TCO gap (depending on the type of semiconductor fab).[18] (See Figure 1.)

Figure 1: Estimated 10-year TCO of reference fabs by location (U.S. indexed to 100)[19]



To offset the effect of foreign incentives to attract semiconductor manufacturing activity and thus level the global playing field, USICA/COMPETES features a $39 billion incentive program, including $19 billion in FY 2022 ($2 billion of which would be allocated for legacy chip production) to match state/regional/local incentives toward fabrication (or other essential) facilities for manufacturing semiconductors. America's competitors have been competing at the national level to attract semiconductor manufacturing for decades, while U.S. states and regions have been left to their own devices to scrape together packages as best they can, and this incentive program could rectify that.

Some have called for the financial support mechanisms envisioned in CHIPS to be structured not as matching grants, but as repayable loans or warrants (options to buy shares at a set price). However, the need is not an emergency bailout of the industry, as per the government's 2008 intervention to rescue the auto industry with a package of loans and warrants.[20] In other words, the issue is not ensuring the short-term viability of the industry, but securing its long-term competitiveness and capturing a greater global share of global production for the United States in this critically important, high-value added industry. That is why any package structured as loans or warrants would be next to worthless: Companies are not capital-short; but they do respond to government incentives around the world.[21] Further, as the incentives are distributed, the first should go toward shovel-ready projects.

Another important set of incentives to attract semiconductor manufacturing are investment tax credits, especially when the 10-year cost of a state-of-the-art fab, including both the initial investment and annual operating costs, can reach up to $40 billion.[22] To that end, the Facilitating American-Built Semiconductors (FABS) Act proposes a 25 percent investment tax credit for semiconductor manufacturing investments, both for manufacturing equipment and the construction of semiconductor manufacturing facilities.[23] Such an investment tax credit shouldn't support only chip production, but the activities of chip design firms as well. While an issue obviously more for

Congress than the Department of Commerce at this point, it's important policymakers don't stop with the CHIPS Act in terms of efforts to support U.S. semiconductor competitiveness.

TALENT PIPELINE

If the United States is to rapidly scale up domestic semiconductor R&D and manufacuring, then it's going to need to ensure it has a sufficient pipeline of talent. As TSMC Chairman Mark Liu noted at a 2019 conference on the state of the global semiconductor industry, "The STEM student shortage is global, and especially so in the semiconductor industry."[24] Or, as Ajit Manocha, president and CEO of SEMI (the industry association for semiconductor equipment and materials manufacturers) put it more bluntly, "The talent shortage is the most critical issue confronting the semiconductor industry today."[25]

To that end, the United States needs to seriously upgrade its domestic science, technology, engineering, and mathematics (STEM) pipeline. For instance, at the collegiate level, for years, the United States has been failing to produce adequate numbers of computer science graduates. One study estimated that, from 2014 to 2024, the number of U.S. annual computer/information technolgy (IT) college graduates, totaling about 60,000, would be 40,000 graduates short of annual U.S. labor market needs.[26] In other words, it foresees a gap of 400,000 needed computer science/IT graduates over that decadal period. Several policies could help America close this STEM talent pipeline gap.

There are approximately 100 STEM-focused high schools in America. Most of these public STEM high schools can provide a deep dive into computer science for interested students and have been proven to be effective in including minorities and students from socioeconomically disadvantaged areas in high-quality STEM education.[27] Doubling the number of STEM high schools would allow more students with a passion and deep ability to excel in computer sciences. Moreover, efforts should be made to ensure that all existing STEM-focused high schools provide a deep and rigorous curriculum in computer science.

Schools—at both the high school and university levels—need to work on generating interest in computer science classes among a broader and more diverse group of students, improving the quality of computer science classes, and expanding the number of available seats in computer science classrooms.[28] Congress could create an incentive program (perhaps slightly increasing available federal research dollars) for universities that expand computer science course offerings and produce more computer science graduates.

For later-stage students, Congress should appropriate $20 million per year for the establishment of an National Science Foundation (NSF)-Industry Ph.D. Fellows Program, to support an additional 1,000 Ph.D. students in STEM fields. The new NSF-industry program would work by enabling industry to contribute $20,250 toward each fellowship, in whatever field(s) the company chooses. NSF would match industry funds dollar-for-dollar.[29]

This matters, because the launae in the domestic STEM talent pipeline reverabates to the graduate and Ph.D. levels. In fact, more than half of doctorate-holders in engineering occupations (56.7

percent) and computer sciences and mathematics jobs (54.6 percent) in the United States are foreign-born, while the figure is 33.9 percent in the physical sciences.[30] Meanwhile, 81 percent of full-time graduate students in electrical engineering programs, and 79 percent in computer science, are international students.[31] Of those international students, a 2019 Congressional Research Service report found that nearly 70 percent of foreign students enrolled in STEM courses came from China and India.[32]

Of course, it has long been a strength of the U.S. innovation system that it attracts the world's best and brightest to study at American universities, especially in STEM fields, but this makes it all the more imperative that U.S. immigration policy ease pathways to citizenship by stapling a green card to diploma earners in STEM fields.[33] Unfortunately, over the past 30 years, the time it takes an applicant to receive a green card has increased from roughly six months to six years.

Likewise, the L-1 visa stimulates U.S. innovation as "a non-immigrant visa for intra-company transfers for candidates who are already working for the company that intends to open or expand operations in the United States. It could also be the U.S. parent company that wants one of its employees working in its subsidiary to work in the United States."[34] The federal government should not restrict L-1 visas.

The U.S. government also needs to expand semiconductor-sector-specific education and workforce training programs. For instance, in 2019, the NSF awarded a $6.5 million grant intended to develop a Semiconductor Workforce Certification Program to be developed collaboratively by the NSF Advanced Technology Education Program (ATE), SEMI, and SUNY Poly and piloted it at 16 technician education programs at two-year and four-year colleges and technical high school programs with the goal of training 400 students to earn a SEMI Semiconductor Technician Certification.[35] The initiative includes a unified competency model, course curriculum, web portal, and engagement with industry and training providers that can provide a pathway to grow the microelectronics manufacturing industry's talent pipeline, both in the United States and abroad.[36] Such programs should be expanded and made available nationwide.

NSF's Advanced Technological Education program supports community colleges working in partnership with industry, economic development agencies, workforce investment boards, and secondary and other higher education institutions; it plays a key role in building America's base of skilled technicians. ATE projects and centers are educating technicians in a range of fields, including nanotechnologies and microtechnologies, rapid prototyping, and biomanufacturing.[37] Notwithstanding this, ATE funding is quite small, at just $75 million in 2020; funding for this program should be doubled to $150 million, as proposed in the Advanced Technological Manufacturing Act.[38] Another way the United States can build its semiconductor-sector-supporting engineering talent base would be by significantly expanding the Manufacturing Engineering Education Grant (MEEG) program.[39] The program supports industry-relevant, manufacturing-focused, engineering training at U.S. institutions of higher education, universities, industry, and nonprofit institutions.[40]

ROLE OF GOVERNMENT IN STIMULATING SEMICONDUCTOR DEMAND

From the beginning, the role of the federal government in being a procurer of semiconductors played a critical role in the growth of the U.S. semiconductor industry, and over time, driving down their prices through scale acquisition to the point semiconductors ultimately became commercially viable products. For instance, the U.S. space program alone consumed one-third of U.S. semiconductor sector output during the 1960s.

While the government's role as an early procurer of semiconductors isn't as important today, the government can play an important role in stimulating greater demand in the United States for semiconductor-using application. For instance, this could include federal and state governments' efforts to modernize the electric grid, implement smart cities and intelligent transportation systems, deploy next generation 5G/6G advanced communication systems, and upgrade other digital infrastructure. To that end, an estimated two-thirds of semiconductor usage is tied to increased computing power (e.g., AI) and connected devices (such as sensors or IoT systems).[41]

While more related to stimulating semiconductor production rather than demand, another way policy can help achieve maximum impact from the CHIPS Act is by including a fast-tracking of federal permitting requirements under National Environmental Policy Act (NEPA), which represents the first step in evaluating the environmental impact of a construction project and studies factors including pollution and biodiversity.[42]

PROMOTING SEMICONDUCTOR SUPPLY CHAIN RESILIENCY

The international semiconductor industry has benefitted tremendously from the evolution of global value chains that have enabled enterprises to specialize in specific facets of semiconductor R&D or production, and this dynamic has played a critical role in helping the industry maintain its Moore's Law trajectory over the past more than four decades. In fact, each of the three major segments of the semiconductor value chain—chip design; wafer fabrication; and ATP—has, on average, 25 countries involved in the direct supply chain and 23 countries involved in support functions. Over 12 countries have enterprises directly engaged in semiconductor chip design, 39 countries have at least one semiconductor fabrication facility, while over 25 countries have enterprises engaging in assembly, testing, and packaging activities.[43]

But while globalization and specialization have historically been (and remain) a strength for the semiconductor industry, recent events such as the COVID-19 pandemic and the conflict in Eurasia have heightened focus on the importance of resiliency and sustainability in semiconductor supply chains. The goal is to identify critical points of dependency and take steps to reduce concentration. For instance, a recent McKinsey Global Institute study identified 180 manufactured products across value chains for which one country accounts for 70 percent or more of exports.[44] Examining the semiconductor supply chain specifically, a report by the Boston Consulting Group found "there are more than 50 points across the supply chain where one region holds more than 65% of the global market share."[45]

To that end, in June 2021, the Biden administration released findings from its 100-day review of four sectors, including semiconductors, finding "long-standing vulnerabilities in U.S. supply chains."[46] ITIF endorses many of the report's proposed recommendations to address these supply chain vulnerabilities, starting with its call to establish a new office within the Department of Commerce to lead a government-wide effort to strengthen supply chains critical to America's economic vitality and national security and to support this endeavor with $45 billion in grants, loans, and loan guarantees to support supply chain resilience and critical goods manufacturing (elements which have been incorporated into the House's America COMPETES Act legislation). Another proposal from the supply chain review which Congress should pursue entails expanding the U.S. Export-Import Bank's ability to use existing authorities to further support domestic manufacturing, including by implementing a new Domestic Financing Program to support the establishment and/or expansion of U.S. manufacturing facilities and infrastructure projects in the United States that would support U.S. exports.

For companies, it's important to note that supply chain resilience need not come at the expense of efficiency, and indeed many companies are starting to deploy more-sophisticated digital tools such as artificial intelligence, blockchain, sensor-enabled IoT systems, etc. to better manage their supply chains. Another approach many are pursuing with regard to key suppliers is a "China + 1" strategy. Here, like-minded allies can play an important role. In particular, the United States should leverage the auspices of the U.S. Development Finance Corporation (DFC) to support supply chain resilience and build-up supply chains of critical products within like-minded nations. Further to that end, the 100-Day supply chain review called on President Biden to establish a Presidential Forum with like-minded nations on supply chain resilience. There's significant opportunity to enhance semiconductor supply chain resiliency by bolstering alternative sources of supply and production among like-minded nations.

Further to this, USICA/COMPETES creates a multilateral security fund to support development and adoption of secure microelectronics and microelectronics supply chains. Such funding should be used to build upon initiatives such as the Center for Secured Microelectronics Ecosystems, a collaboration between TSMC and Purdue University which seeks to ensure a secure supply of semiconductor chips and related tools all the way from the foundry to the packaged system, with the goal of developing advanced chips that could be detected or traced if security concerns arise.[47]

In conclusion, ITIF applauds the Biden administration, executive agencies', and Congress's focus on enhancing U.S. semiconductor industry competitiveness. Governments throughout the world are developing aggressive, sophisticated approaches to support the competitiveness of their semiconductor industries; it's imperative the United States does the same.

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