Chapter 13: Microelectronics
Rebuilding U.S. Microelectronics Leadership

Stay Two Generations Ahead in Microelectronics

Multiple Sources of Domestic Cutting-Edge Manufacturing

National Microelectronics Strategy

Double Down on Microelectronics R&D

Tax Credits and Grants for U.S. Fabrication Facilities
U.S. leadership in microelectronics is critical to overall U.S. leadership in artificial intelligence (AI). Several assessments underpin this argument:

- Hardware is a foundational element of the AI stack alongside data, algorithms, and talent.¹
- Exponential increases in computational power have driven the last decade of progress in machine learning (ML).²
- After decades leading the microelectronics industry, the United States will soon source roughly 90% of all high-volume, leading-edge integrated-circuit production from countries in East Asia.³ This means the United States is almost entirely reliant on foreign sources for production of the cutting-edge semiconductors critical for defense systems and industry more broadly, leaving the U.S. supply chain vulnerable to disruption by foreign government action or natural disaster.
- Specialized hardware, novel packaging techniques such as heterogeneous integration and 3D stacking, and new types of devices will drive future AI developments as traditional architectures of silicon-based chipsets encounter diminishing marginal performance improvements.⁴
- Demand for trusted microelectronics will only grow as the military and Intelligence Community (IC) continue to incorporate AI into mission-critical systems.⁵

“... the United States is almost entirely reliant on foreign sources for production of the cutting-edge semiconductors critical for defense systems and industry more broadly, leaving the U.S. supply chain vulnerable to disruption by foreign government action or natural disaster.”
U.S. leadership in semiconductors has long been taken for granted based on America's advantage as a pioneer of the microelectronics industry. Gradually, however, the United States has been losing its edge. Although American universities and firms remain global leaders in the key areas of semiconductor R&D and chip design, the semiconductor industry is now highly globalized and competitive. Taiwan Semiconductor Manufacturing Corporation (TSMC) leads the world in semiconductor contract manufacturing, and Samsung in South Korea is also producing state-of-the-art logic chips. TSMC also leads in the production of ARM-based chips, which is becoming the predominant chip architecture for mobile devices, servers, and other key applications of emerging technologies. In a bid to catch up and achieve chip self-sufficiency, China is pursuing unprecedented state-funded efforts to forge a world-leading semiconductor industry by 2030. Although China is behind firms headquartered in Taiwan, South Korea, and the U.S. in terms of chip manufacturing, it is advancing quickly. Meanwhile, Intel, the leading U.S. manufacturer, remains competitive in chip design but has faced manufacturing setbacks for leading-edge chips and may fall further behind its rivals in Taiwan and South Korea. Current projections put the firm two generations or more behind the cutting-edge node by 2022. These and other concerning trends indicate that America's leadership in microelectronics is eroding, especially in manufacturing, assembly, testing, and packaging.

The dependency of the United States on semiconductor imports, particularly from Taiwan, creates a strategic vulnerability for both its economy and military to adverse foreign government action, natural disaster, and other events that can disrupt the supply chains for electronics. Despite tremendous expertise in microelectronics research, development, and innovation across the country, the United States is constrained by a lack of domestically-located semiconductor fabrication facilities, especially for state-of-the-art semiconductors. If current trends continue, the United States will soon be unable to catch up in fabrication, and could eventually also be outpaced in microelectronics design. If a potential adversary bests the United States in semiconductors over the long term or suddenly cuts off U.S. access to cutting-edge chips entirely, it could gain the upper hand in every domain of warfare. Focusing the efforts of the U.S. Government, industry, and academia to develop domestic microelectronics fabrication facilities will reduce dependence on imports, preserve leadership in technological innovation, support job creation, improve national security and balance of trade, and enhance the technological superiority and readiness of the military, which is an important consumer of advanced microelectronics.
“Despite tremendous expertise in microelectronics research, development, and innovation across the country, the United States is limited by a lack of domestically-located semiconductor fabrication facilities ...”


- SMIC (China)
- Intel (USA)
- TSMC (Taiwan)
- Samsung (Republic of Korea)

Node size for 2021-2024 are projections and reflect firm roadmaps

Node size reflects estimated first year of mass production

No roadmap displayed beyond 2021 for SMIC due to export control restrictions on materials currently required for production beyond 14 nm
To regain U.S. leadership in microelectronics, the Executive Branch should finalize and implement a national microelectronics leadership strategy. Additionally, Congress should create a 40% refundable tax credit for domestic fabrication investments by firms from the United States and its allies and appropriate an additional $12 billion over the next five years for microelectronics research, development, and infrastructure. Together these efforts will enable the U.S. government, private sector, and academia to rise to the challenge of rebuilding U.S. semiconductor superiority.

Objective: Stay two generations ahead of China in state-of-the-art microelectronics and maintain multiple sources of cutting-edge microelectronics fabrication in the United States.

The United States should focus the attention and resources necessary for long-term competition in microelectronics by adopting an overarching national objective: to stay two generations ahead of potential adversaries in state-of-the-art microelectronics while also maintaining multiple sources of cutting-edge microelectronics fabrication inside the United States. While the United States has historically led China by at least two generations in semiconductor design and fabrication, this has not been an explicit policy goal. And while China has not been able to surpass the United States, other nations such as Taiwan and South Korea now clearly lead the U.S. in state-of-the-art semiconductor manufacturing. This leaves the U.S. reliant on foreign sources for critical inputs to defense systems and U.S. industry more broadly. Yet the United States retains a strong position in segments of the global value chain for semiconductors, such as design, electronic design automation tools, and semiconductor manufacturing equipment (SME). Therefore, an objective to rebuild microelectronics leadership should be stated plainly to concentrate national support across government, industry, and academia on regaining leadership in sectors such as semiconductor fabrication where the United States has fallen behind and also to track progress over time against a clear yardstick. To achieve this objective, the Commission recommends focusing action along three fronts:

- **Implementing a national microelectronics strategy:**
- **Revitalizing domestic microelectronics fabrication by incentivizing multiple cutting-edge domestic fabrication facilities;** and
- **Ramping up microelectronics research.**

In addition to these efforts to promote U.S. microelectronics leadership, the United States and its allies should utilize targeted export controls on high-end semiconductor manufacturing equipment, described in Chapter 14 of this report, to protect existing technical advantages and slow the advancement of China’s semiconductor industry.
Implement the National Microelectronics Strategy. The United States lacks a national microelectronics strategy to coordinate semiconductor policy, funding, and incentives within the Executive Branch and externally with industry and academia. A truly national strategy would build on this Commission’s work as well as previous studies conducted by the United States government or on its behalf. It would also integrate the disparate approaches of the Departments of State, Defense, Energy, Commerce, and Treasury, and other relevant agencies, to promote domestic R&D and semiconductor manufacturing expertise while preventing the illicit transfer of technology to competitors. Finally, it would be updated on a consistent basis to foster a coordinated approach and adapt to shifting challenges to microelectronics innovation, competitiveness, and supply chain integrity.

In line with the Commission’s recommendations, the Fiscal Year 2021 National Defense Authorization Act (NDAA) creates a subcommittee of the National Science and Technology Council (NSTC), consisting of senior government officials, to develop a National Strategy on Microelectronics Research and oversee its implementation. However, for this key effort to be successful, it should be prioritized by the White House by requiring the NSTC subcommittee to submit the National Microelectronics Strategy to the President within 270 days.

Revitalize domestic microelectronics fabrication. The Commission concludes that the United States is overly dependent upon globally diversified supply chains for microelectronics, including imports from potential adversaries. Furthermore, as a result of gaps in the U.S. industrial base, the risks are increasing that the United States could lose access to trusted, assured, and state-of-the-art semiconductors for national security use cases. Despite these concerns, the Commission has been encouraged by a number of developments over the past year to revitalize the domestic fabrication of state-of-the-art microelectronics.
Examples include TSMC’s decision to develop an advanced facility in the United States and Intel’s publicly stated interest in working with the United States government to develop a commercial U.S. foundry. However, these are only initial steps, and more must be done by the U.S. government to reach an end state where multiple firms are fabricating state-of-the-art chips domestically. Without several U.S.-based fabrication facilities, both U.S. industry and U.S. national security face risks from competitive pressures and supply chain shortages. The most significant recent development has been the inclusion of several semiconductor-related provisions from the “CHIPS for America Act” in the Fiscal Year 2021 National Defense Authorization Act (NDAA). However, these programs require sufficient appropriations to succeed, and they did not receive appropriated funding in Fiscal Year 2021, which leaves congressional priorities unclear. Further congressional action to establish refundable investment tax credits and set the conditions for the domestic production of advanced microelectronics will be important to enable the United States to remain two generations ahead of China. Specifically, the U.S. government should:

- **Incentivize domestic leading-edge merchant fabrication through refundable investment tax credits.** Although introduced as part of the CHIPS for America Act, Congress has not yet passed legislation establishing a 40% refundable investment tax credit for semiconductor facilities and equipment. Existing U.S. incentives reduce the cost of foundry construction attributable to capital expenses, operating expenses, and taxes by just 10% to 15%. A credit of this magnitude is needed to make the United States a competitive market for semiconductor manufacturing, as other leading semiconductor manufacturing nations such as South Korea, Taiwan, and Singapore offer 25% to 30% cost reduction, roughly double what the United States currently offers. This gap in incentives is one driving factor behind the lack of an advanced logic merchant foundry in the United States. Closing the incentive gap and broadening it to include companies from allied countries will incentivize U.S. firms to construct facilities domestically while also attracting foreign firms such as TSMC and Samsung. Additionally, increasing demand in the United States for high-end SME will create new business opportunities for SME manufacturers from allied countries, particularly Japan and the Netherlands, which could increase their governments’ willingness to align their export control policies with strict U.S. policies prohibiting the export of such equipment to China.
“... other leading semiconductor manufacturing nations such as South Korea, Taiwan, and Singapore offer 25 to 30 percent cost reduction, roughly double what the United States currently offers.”

Double-down on federally funded microelectronics research. Each succeeding generation of chips using traditional architectures of silicon-based transistors faces diminishing marginal gains to performance as they reach the limits imposed by the laws of physics. As a result, the relative advantage the United States has enjoyed by staying roughly two generations ahead of potential adversaries in the design phase of developing cutting-edge hardware could decrease over time as the gap between hardware generations narrows. Therefore, the United States must look to heterogeneous integration and other novel hardware improvements in the medium term to continue out-innovating competitors. Over the longer term, the United States must also continue its portfolio approach to future microelectronics pathways by investing in new materials and entirely new hardware approaches, such as quantum and neuromorphic computing. Broad-based investments and incentives will also be important to maintain leadership in other areas of U.S. strength related to semiconductor manufacturing, including electronic design automation tools and SME.

Four primary research arms of the United States government focused on both medium- and long-term microelectronics breakthroughs are the Department of Energy, Defense Advanced Research Projects Agency (DARPA), National Science Foundation (NSF), and the Department of Commerce, primarily through engagement with industry. Their suite of existing programs, such as DARPA’s Electronics Resurgence Initiative, is targeting the right research areas but must expand by an order of magnitude to achieve the necessary breakthroughs and maintain U.S. competitiveness. Additional funding should support not only research projects, but also the capital-intensive underlying infrastructure for microelectronics development, including the National Semiconductor Technology Center and advanced packaging prototyping activities authorized in the Fiscal Year 2021 NDAA. In particular, advances in packaging will be critical to future improvements in semiconductor
capabilities as firms reach physical limits for two-dimensional transistor density. The government should:

• **Double down on federal research funding to lead the next generation of microelectronics.** The Commission recommends substantially increasing the United States government’s full range of research efforts focused on microelectronics. Congress should appropriate an additional $1.1 billion for semiconductor research and $1 billion for the Advanced Packaging National Manufacturing Program in Fiscal Year 2022. Building on these investments, these funding levels should continue for five years, for a total investment of roughly $12 billion. These amounts are consistent with the funding levels introduced, but not yet appropriated, in the CHIPS for America Act and the American Foundries Act of 2020. In line with the existing focus areas of these programs and the Commission’s prior recommendations, the funding should be applied to developing infrastructure and pursuing breakthroughs in promising areas such as next-generation tools beyond extreme ultraviolet lithography, 3D chip stacking, photonics, carbon nanotubes, gallium nitride transistors, domain-specific hardware architectures, electronic design automation, and cryogenic computing.

“... advances in packaging will be critical to future improvements in semiconductor capabilities as firms reach physical limits for two-dimensional transistor density.”
Chapter 13 - Endnotes


2 Recent machine learning (ML) breakthroughs have relied heavily on computing power, and the amount of compute used in the largest AI training runs has been increasing exponentially since 2012. Girish Sastry, et al., Addendum: Compute Used in Older Headline Results, OpenAI (Nov. 7, 2019), https://openai.com/blog/ai-and-compute/#addendum.


11 The Commission’s previous reports offered a range of initial recommendations to expand access to trusted semiconductors, increase microelectronics R&D funding, control the export of high-end semiconductor manufacturing equipment to adversaries, and reshore leading-edge fabrication facilities.


15 See Pub. L. 116-283, William M. (Mac) Thornberry National Defense Authorization Act for Fiscal Year 2021, 134 Stat. 3388 (2021). These provisions authorize several programs the Commission has previously identified as essential to U.S. microelectronics leadership. In particular, the provisions would require drafting a National Microelectronics Leadership Strategy, establishing a National Semiconductor Technology Center, and creating an incubator for semiconductor startup firms and an Advanced Packaging National Manufacturing Institute, all of which align with previous recommendations from the Commission.

16 This incentive would reduce a semiconductor firm’s tax bill by 40% on semiconductor manufacturing equipment and facilities through 2024, followed by reduced tax credit rates of 30% and 20% respectively, through 2025 and 2026.


18 See Chapter 14 of this report for additional details on export controls on SME.


20 See S. 3933 and H.R. 7178, Creating Helpful Incentives to Produce Semiconductors (CHIPS) for America Act, 116th Congress (2020).