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A Seismic Shift

The New U.S. Semiconductor Export Controls and the Implications for U.S. Firms, Allies, and the Innovation Ecosystem

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On October 7, 2022, the Department of Commerce's Bureau of Industry and Security (BIS) announced sweeping revisions to its export controls, which are aimed at restricting China's ability to obtain certain high-end semiconductor devices with potential military applications, develop and maintain supercomputers, and manufacture advanced semiconductor devices.

This announcement, the most expansive export control action in decades, represents a fundamental shift in the traditional strategy underlying the U.S. and allied export control regime. As National Security Advisor Jake Sullivan put it, until now, "we previously maintained a 'sliding scale' approach that said we need to stay only a couple of generations ahead. That is not the strategic environment we are in today. Given the foundational nature of certain technologies, such as advanced logic and memory chips, we must maintain as large of a lead as possible." In effect, the new measures are intended to dramatically slow, if not freeze Chinese developmental capability.

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The U.S. moves are a reaction to new emphasis on China's Military-Civil Fusion doctrine, under which China's civilian technology sector is expected to more closely support the military sector. Ironically, the U.S. measures are a mirror image of China's Made in China 2025 program, which is designed to reduce Chinese dependency on Western sources. The BIS action is also a tacit acknowledgement of the rapid technological strides China is making and the realization that if China does manage to leapfrog the United

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States and its allies in chip technology, it will gain the upper hand militarily "in every domain of warfare," as one recent U.S. study of artificial intelligence (AI) concluded.

U.S. dependency on foreign production for all of the most advanced chips needed for AI, satellite communications, and military and space programs has become a major national security concern. In an interview, Secretary of Commerce Gina Raimondo warned of China's heavily subsidized drive to achieve leadership in the most advanced technologies. She said that the new BIS rules are "our defensive strategy. . . . [and] the next logical step, to prevent China from getting to the next step." One industry observer characterized the new rules as "a form of technology containment. Not just to stay ahead of China, but to degrade their ability to try to catch up with us."

These objectives represent an unprecedented departure from the precepts of the integrated global economy. For these ambitious objectives to be achieved, the recent export control actions will require broad and sustained follow-through. The measures will require a significant adjustment on the part of the semiconductor industry, as well as a new emphasis on strategic cooperation among allies to maintain collective technology leadership. For this strategy to succeed over the long term, the United States will need a national commitment to bring together the necessary industry and policy expertise, legislate or implement the necessary authorities, and form new institutional arrangements. It can be done, but it will require continuing the high-level attention seen thus far.

Objectives and Features of the Export Controls

As pointed out in a recent white paper by Greg Allen, director of the CSIS AI Governance Project, the new rules have four broad objectives which, taken together, are intended to limit China's technological development in microelectronics for the foreseeable future. They are intended to:

- **Limit AI Chip Access:** The controls intend to cut off China's access to advanced semiconductor devices needed for supercomputing and AI applications.
- **Limit Design Capability:** The controls intend to block China's access to U.S. design software to prevent China from designing high-end semiconductors.
- **Stifle Advanced Chip Manufacturing Capability:** The controls block China's access to U.S.-made semiconductor manufacturing equipment, for which there is no foreign alternative, to prevent China from manufacturing advanced chips.
- **Limit Manufacturing Equipment Capability:** The controls seek to prevent China from building state-of-the art semiconductor manufacturing equipment by blocking access to U.S.-made chips needed to make such equipment.

To do this, the BIS rules have a number of distinctive features. Although in general they utilize existing tools that have been used separately before—such as foreign direct product rules, creation of new export control classification numbers (ECCNs), regional stability controls, and licensing requirements for persons—in this case they are layered together to target specific technologies in an unprecedented manner. The net result is a comprehensive scheme to impair China's development of its AI and supercomputing capability by shutting down access to the chips and manufacturing equipment essential to that capability.

Key specific details include:

- **Blocking Expert Assistance by U.S. Nationals:** The new BIS regulations prohibit U.S. engineers and scientists from providing assistance to China in semiconductor manufacturing even if those individuals are working on tools that are not subject to export controls.
- **Tightening Licensing Requirements:** Licensing requirements are tightened for exports of items destined for a supercomputer or semiconductor "located in or destined to the [People's Republic of China, or PRC]."
- **Exercising a Presumption of Denial:** Export licenses for semiconductor manufacturing items destined for China will be considered with a presumption of denial. The new regulations effectively cut off Chinese access to U.S. semiconductor design and manufacturing equipment supporting the production of logic chips utilizing design rules of 14 and 16 nanometers (nm) or lower, for production of DRAMs (dynamic random-access memory) 18 nm or better, and for NAND memories 128 layers or higher.
- **Adding Entities to the Unverified List:** BIS concurrently added 31 Chinese entities to its Unverified List, eliminating their ability to receive any items subject to the Commerce Department's Export Administration Regulations (EAR).
- **Extending the Foreign Direct Product Rule:** The new regulations include a so-called foreign direct product rule, which prohibits U.S. and non-U.S. companies from supplying Chinese buyers with certain hardware or software incorporating U.S. technology or software. This rule will prevent companies worldwide from supplying Chinese entities with designated advanced chips made with U.S. technology without a U.S. government license.
- **Scrutinizing Investments:** The Biden administration is also reportedly preparing an executive order that would enable the federal government to scrutinize overseas investments by U.S. companies from a national security perspective, which will impact the offshore chip design and manufacturing activities of U.S. companies.

Industry Reactions

The BIS announcement has already had dramatic repercussions for the semiconductor market and the business operations of chip firms across the supply chain. Stock prices for Asian chipmakers plummeted in the wake of the BIS action. Industry experts forecast new supply chain disturbances in an industry already hard-hit by Covid-19 disruptions. Days after the BIS announcement, the head of a leading Taiwanese supplier to Apple warned the tech world to get ready for "casualties and consequences" from the U.S. measures, likening them to "earthquakes."

- Foreign semiconductor equipment suppliers that support chipmaking operations in China have begun to curtail their operations and withdraw support personnel from Chinese fabs.
- Korean chipmaker SK Hynix has indicated it may sell its chip memory production operations in China, citing the BIS measures.
- ASML, the world's leading semiconductor lithography equipment maker, has reportedly directed its U.S. staff to stop serving Chinese customers while it assesses the new U.S. sanctions.
- Apple has reportedly put on hold plans to source memory chips from China's Yangtze Memory Technology Company (YMTC), citing geopolitical pressure and criticism from U.S. policymakers.

- The new U.S. restrictions leave at least 43 senior executives who are U.S. citizens working inside Chinese chip firms "in limbo," facing a potential choice between "their jobs and U.S. citizenship or permanent residence status."

Some foreign firms, such as the Taiwan Semiconductor Manufacturing Company (TSMC) and South Korea's Samsung and SK Hynix, have secured one-year licenses from the Department of Commerce to continue their operations in China, but these firms regard the department's actions as a "warning" rather than an "olive branch."

Concerns on Supply Chain Impacts

Firms from across the global semiconductor supply chain are raising a variety of concerns over the impact that the new measures will have on the complex chip research and production ecosystem. Some firms point to a pressing need for predictability in government policies, given the long lead-times they need to plan research and production investments and to form business partnerships and supply arrangements. The scrambling by chip firms in the wake of the October BIS announcement suggests that at least some of them were caught unprepared despite indicators over the past year. As one former undersecretary of commerce for export administration put it, "the change . . . is not a surprise. For more than a year, I have been suggesting that our policy may have run out of gas."

More Precision: Others call for more precision in the targeting of export controls. They note that the new rules, in some cases, target widely available technologies where alternative suppliers can be lined up as the need arises. They also worry that some foreign firms will "design out" U.S. technologies if it becomes too hard to comply with the export control restrictions. In such cases, U.S. firms may lose their customers within the space of a few years.

Reduced Research: Some U.S. semiconductor firms point out that the recently announced export controls will have negative ripple effects on their future investment in research. U.S. industry consistently accounts for around 50 percent of global chip sales by revenue—China being by far the largest single market. The sanctions, these firms predict, will significantly reduce that 50 percent share, thereby reducing revenue meant to fund research for the next generation of chips or equipment.

A Crucial Role for "Legacy Chips": U.S. firms that design and make legacy chips (older generations of less-sophisticated semiconductors) also point out that export controls, while negatively affecting their business models and profitability, are unlikely to have much impact on China's strengths in manufacturing legacy chips, in which China continues to pour investments. While these are not the smallest cutting-edge devices, they are nonetheless hugely important economically in that they account for a large portion of the chips used in automobiles, consumer electronics, and information and telecommunication products, as well as many weapons systems. Large export volumes of state-supported legacy chips could prove extremely disruptive to the market shares and profitability of existing Western producers.

As noted, the new U.S. measures collectively represent a dramatic change that creates new realities that will necessitate a rewiring of the global semiconductor ecosystem. Firms in the industry will have to adapt by recalculating business models, developing new shared standards, updating roadmaps, and forging new, more resilient partnerships up and down the supply chain. The changes are likely to be both costly and disruptive to one of the world's most globalized industries.

Allied Reactions

For this ambitious policy to succeed, support from U.S. allies will be essential. Companies are already cautioning that if U.S. allies do not implement complementary export controls, the U.S. sanctions will simply cause Chinese buyers to "revise their shopping lists"—replacing U.S. devices and equipment with comparable foreign components. Indeed, key foreign allies have yet to impose similar measures. These include the governments of Europe, Japan, South Korea, and Taiwan, whose companies are key sources of design, equipment, and materials technology, as well as specialized know-how for manufacturing the most advanced chips. If Chinese firms can acquire semiconductor devices, software, equipment, materials, and know-how from these countries, the effectiveness of the BIS sanctions will be limited over time.

A Unilateral Move

The new export control rules **were imposed** by the United States unilaterally, reportedly after inconclusive discussions with U.S. allies earlier in 2022. In briefings after the October announcement, U.S. officials **acknowledged** that they had not secured any commitments with allied nations to implement similar restrictions and that "discussions with those nations are ongoing," noting further that "We recognize that the unilateral controls that we are putting in place will lose effectiveness over time if other countries don't join us." Some foreign observers note that coordinating with allies on a rules- and principles-based approach to export controls from the United States might gain more traction among allies than an approach that is perceived as unilateral. On the other hand, winning agreement on measures of this scope and severity is unlikely to be rapid and might well prove elusive.

Some observers are hopeful that the so-called Ukraine effect will foster a joint allied stance on limiting China's technological power. This effect refers to the solidarity that enabled the United States and its allies to establish comprehensive trade and financial sanctions on Russia in the wake of its invasion of Ukraine—coordinated action that would have been inconceivable a year ago. As National Security Advisor Jake Sullivan **pointed out**, the United States and its allies and partners levied "the most stringent technology restrictions ever imposed on a major economy," which have had a perceptible impact on the battlefield in Ukraine, "forcing Russia to use chips from dishwashers in its military equipment." But the unprecedented allied cohesion in the face of Russia's attack arose out of a combination of shared concern for protecting democratic values, shock at naked military aggression, and the immediate threat to European security and borders. With respect to China, perceptions of the immediacy and dimensions of the threat vary from ally to ally.

Proponents of the rules argue that inaction is not an option. Developing a potent, consensus-driven approach would have been difficult to achieve in a reasonable timeframe. Extended negotiations would likely have compelled the Chinese to take proactive measures, including redoubled efforts to divide the alliance. Timing also matters; for now, the United States still has the upper hand in this strategic environment, and it needed to act while it could still influence outcomes. That said, sustained coordination among U.S. allies will be necessary going forward to forestall workaround solutions to the export controls.

Assessing the Impact on China

A fundamental question is whether these policy measures will work in practice. Can a U.S.-led microelectronics technology embargo against China succeed in delaying or preventing China from surpassing the United States and its allies in semiconductor design and manufacture, with all of the strategic implications such an outcome would have?

Views differ, but one authoritative source, Peter Wennink, the CEO of ASML, the Dutch firm which makes the most advanced semiconductor lithography equipment in the world, argues that Western restrictions on chip technology exports to China will ultimately prove counterproductive. In a 2021 interview, he said that "if you shut out the Chinese with export control measures, you'll force them to strive toward tech sovereignty, in their case real tech sovereignty. . . . In 15 years' time, they'll be able to do it all by themselves—and [Western equipment suppliers'] market . . . will be gone." Tudor Brown, a former independent director at China's leading chipmaker, Semiconductor Manufacturing International Corporation (SMIC), concurs: "The US is being naive if it thinks this is going to slow them down for any length of time. I think it will slow them down for two to five years, not 10."

Some recent technological strides by Chinese semiconductor device and equipment makers, which have been achieved despite U.S. export controls, would seem to support bullish perspectives on China's ability to achieve chip self-sufficiency:

- SMIC, the most advanced Chinese chip manufacturer, has caused a stir by announcing that it is producing 7 nm devices. The claim is unverified, but if it is real, it was achieved despite the fact that SMIC is barred by Western export controls from acquiring extreme ultraviolet light (EUV) lithography equipment made by ASML—equipment assumed to be a prerequisite to chip fabrication at the 7 nm node.
- Chinese chip firms are also reported to be developing technological "workarounds" that help bridge the gap with more advanced Western chips, including "clever packaging" and maximum use of DUV (deep ultraviolet) ArF (argon fluoride) immersion lithography.
- Chinese semiconductor equipment maker AMEC is making etching equipment of sufficient quality that it is reportedly being tested by the world's most advanced semiconductor device makers, including TSMC (Taiwan), Samsung (South Korea), Intel, and Micron Technologies (United States).
- And a Chinese lithography equipment maker, SMEE, is reportedly working on an ArF immersion lithography tool that can be used to produce semiconductor devices at the 5 nm node.

Key Challenges Facing China

Despite such developments, there are major obstacles that will make it difficult for China to catch up with—much less overtake—global chip leaders in the foreseeable future.

First, the sheer cost and technological demands of leading-edge chipmaking make it very hard to achieve national self-sufficiency in all aspects of semiconductor design and manufacturing. In terms of cost, the Boston Consulting Group estimated in 2021 that it would cost any country $1 trillion to achieve a self-sufficient chip supply chain. Further, the immense complexity and scale of semiconductor research, design, and production networks—a system that has evolved over 60 years—means that no company, however well managed, and no country, however large or well-endowed, can expect to achieve technological superiority in semiconductors if isolated from the international microelectronics technology ecosystem.

Indeed, neither Taiwan nor South Korea built a substantial infrastructure of chipmaking equipment, materials, and services suppliers on their own. They succeeded by sourcing these key factors of production internationally and building their internal know-how through high-volume production, sustained investments, and careful attention to all aspects of the manufacturing process. Today, the fabs of these nations' device firms are closely supported by local networks of equipment, materials, and service firms, most of which have on-site personnel within the fabs to ensure their smooth operation and to

troubleshoot problems. Most of these local operations in Taiwan and South Korea are foreign owned. Without continued access to their products—along with the extraordinary expertise and operational support that supplier firms provide their customers—Taiwan's TSMC and South Korea's Samsung would see their current competitive standing erode.

At time of writing, foreign semiconductor equipment firms are withdrawing their experts from Chinese chip fabs. China also **currently lags** significantly behind the major global players in virtually every aspect of semiconductor device, equipment, and materials technology. As a recent analysis of Chinese chip efforts point outs, the demands of Moore's Law and the race to move to the next production node make catching up with the global leaders **extremely difficult**: "even as Chinese chipmakers work hard to catch up, Intel, Samsung, and TSMC are still racing ahead."

Reflecting these realities, China to date has not adopted a go-it-alone developmental strategy. Rather, the Chinese effort emphasizes acquisition and absorption of foreign chip technologies through purchase of foreign semiconductor enterprises or theft of their technology. Their approach also **includes** attracting talent from foreign chip firms, bargaining with foreign firms for technology transfer in exchange for access to the Chinese market, and a policy of encouraging "indigenous innovation" by Chinese enterprises—**defined** as "enhancing original innovation through co-innovation and re-innovation based on the assimilation of imported technologies." To drive technology transfers, Chinese antimonopoly law enforcers **have levied** massive fines against foreign semiconductor firms for alleged "excessively high" technology licensing fees and "unreasonable" terms for patent licensing.

While China has demonstrated it will commit unprecedented sums to chip manufacturing, many industry experts believe that this **will not be** sufficient. Investments alone, no matter how large, are unlikely to deliver technological parity. TSMC and Samsung's leadership was primarily a function of foreign transfer of know-how and technology, not capital outlays. That said, China is determined to advance its objectives and has assembled a national leadership committed to those goals. China's leadership sees this as a national imperative, essential for the country's place in the world. Given this view, China will dedicate significant financial, intellectual, and diplomatic resources to evade and overcome U.S. efforts at containment.

Long-Term Commitment

The Biden administration's export controls are designed to stifle the transfer of equipment, devices, and know-how to China and ensure that technological parity with the West is neither achieved nor achievable, no matter how much money China commits to its effort. In **recent remarks**, Under Secretary of Commerce for Industry and Security Alan Estevez stressed the national security imperative of imposing controls on high-end AI and supercomputing chips being acquired by China. Addressing concerns about the unilateral nature of the new rules, Under Secretary Estevez expressed confidence that an international agreement with critical allies would be struck before foreign equivalents for U.S.-made technology could be developed. He also emphasized that the controls for semiconductors were just the beginning, suggesting new rules on exports of several other critical technologies are under consideration.

To successfully implement this strategy, the United States has to prepare itself for a sustained, multifaceted, and "all-of-government" effort, one that must include close consultation with the industry itself and U.S. allies. At present, however, the U.S. government is arguably under-equipped, under-resourced, and underinformed about the industry and its often intricate global supply chains. Enforcement is the key to effectiveness, but at least in some cases the data critical to enforce these rules is not readily available. At present, the government relies on industry reporting, with limited internal capacity to analyze and

track its complexity. It appears that the U.S. intelligence and defense communities are significantly (and perhaps understandably) less knowledgeable than the private sector on the global operations of the industry. Expanded recruitment and long-term partnerships with the private sector will be required to bring the necessary expertise to bear. There is a pressing need to attract this expertise, legislate the necessary authorities, and create new institutional structures to make this strategy effective through the long term. ■

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