‘An Act of War’: Inside America’s Silicon Blockade Against China

The Biden administration thinks it can preserve America’s technological primacy by cutting China off from advanced computer chips. Could the plan backfire?

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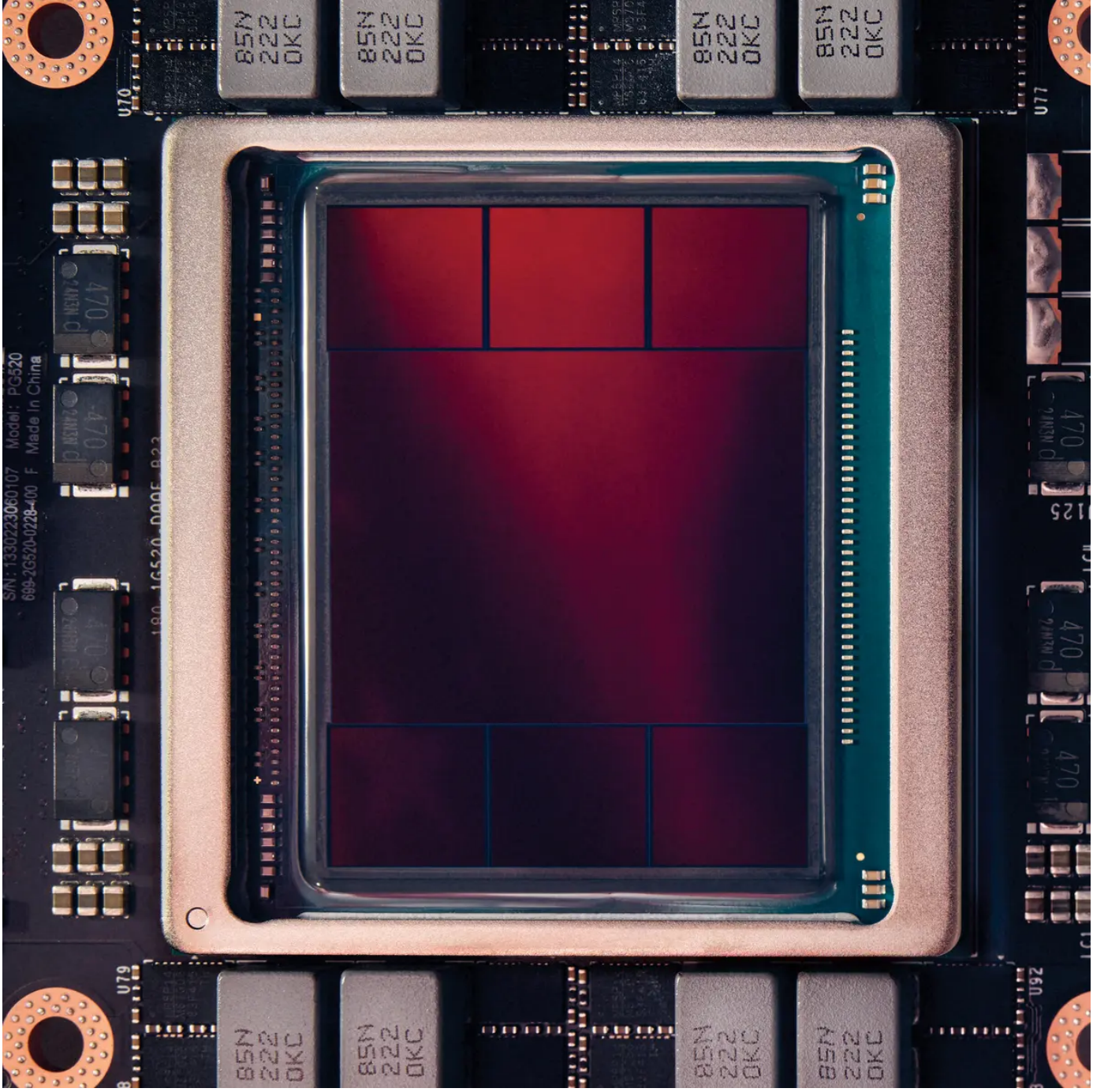

The Nvidia H100 Tensor Core GPU is used for large-scale A.I., high-performance computing and data-analytics workloads.Photo illustration by Grant Cornett for The New York Times

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Last October, the United States Bureau of Industry and Security issued a document that — underneath its 139 pages of dense bureaucratic jargon and minute technical detail — amounted to a declaration of economic war on China. The magnitude of the act was made all the more remarkable by the relative obscurity of its source. One of 13 bureaus within the Department of Commerce, the smallest federal department by funding, B.I.S. is tiny: Its budget for 2022 was just over $140 million, about one-eighth the cost of a single Patriot air-defense missile battery. The bureau employs approximately 350 agents and officers, who collectively monitor trillions of dollars' worth of transactions taking place all around the world.

During the height of the Cold War, when export controls to the Soviet bloc were at their strictest, B.I.S. was a critical hub in the Western defenses, processing up to 100,000 export licenses annually. During the relative peace and stability of the 1990s, the bureau lost some of its raison d'être — as well as staff and funding — and licenses shriveled to roughly 10,000 per year. Today, the number is 40,000 and climbing. With a sprawling trade blacklist known as the entity list (currently 662 pages and counting), numerous pre-existing multilateral export-control agreements and ongoing actions against Russia and China, B.I.S. is busier than ever. "We spend 100 percent of our time on Russia sanctions, another 100 percent on China and the other 100 percent on

everything else," says Matt Borman, the deputy assistant secretary of commerce for export administration.

In recent years, semiconductor chips have become central to the bureau's work. Chips are the lifeblood of the modern economy, and the brains of every electronic device and system, from iPhones to toasters, data centers to credit cards. A new car might have more than a thousand chips, each one managing a different facet of the vehicle's operation. Semiconductors are also the driving force behind the innovations poised to revolutionize life over the next century, like quantum computing and artificial intelligence. OpenAI's ChatGPT, for example, was reportedly trained on 10,000 of the most advanced chips currently available.

With the Oct. 7 export controls, the United States government announced its intent to cripple China's ability to produce, or even purchase, the highest-end chips. The logic of the measure was straightforward: Advanced chips, and the supercomputers and A.I. systems they power, enable the production of new weapons and surveillance apparatuses. In their reach and meaning, however, the measures could hardly have been more sweeping, taking aim at a target far broader than the Chinese security state. "The key here is to understand that the U.S. wanted to impact China's A.I. industry," says Gregory C. Allen, director of the Wadhwani Center for A.I. and Advanced Technologies at the Center for

Strategic and International Studies in Washington. “The semiconductor stuff is the means to that end.”

Though delivered in the unassuming form of updated export rules, the Oct. 7 controls essentially seek to eradicate, root and branch, China’s entire ecosystem of advanced technology. “The new policy embodied in Oct. 7 is: Not only are we not going to allow China to progress any further technologically, we are going to actively reverse their current state of the art,” Allen says. C.J. Muse, a senior semiconductor analyst at Evercore ISI, put it this way: “If you’d told me about these rules five years ago, I would’ve told you that’s an act of war — we’d have to be at war.”

If the controls are successful, they could handicap China for a generation; if they fail, they may backfire spectacularly, hastening the very future the United States is trying desperately to avoid. The outcome will likely shape U.S.-China competition, and the future of the global order, for decades to come. “There are two dates that will echo in history from 2022,” Allen says. “The first is Feb. 24, when Russia invaded Ukraine; and the second is Oct. 7.”

Despite the immense intricacy of their design, semiconductors are, in a sense, quite simple: tiny pieces of silicon carved with arrays of circuits. The circuits flip on and off based on the activity of switches called transistors. When a circuit is on, it produces a one; off, a zero. The first chips,

invented in the late 1950s, held only a handful of transistors. Today the primary semiconductor in a new smartphone has between 10 and 20 billion transistors, each about the size of a virus, carved like a layer cake into the structure of the silicon.

The rate of progress over the last six decades has been famously described by Moore's Law, which observed that the number of transistors that can be fit on a chip has roughly doubled every two years. Chris Miller, author of the book "Chip War" and an associate professor of international history at the Fletcher School at Tufts University, likes to note that if airplanes had improved at the same rate as chips, they'd now be flying at several times the speed of light. No technology in the history of human civilization has ever matched the breathtaking ascent of computing power.

Semiconductor-manufacturing plants, known as fabs, are the most expensive factories in the world, conducting the most complex manufacturing ever accomplished, at a scale of production never before achieved with any other device. The wider chip industry, meanwhile, is a web of mutual interdependence, spread all over the planet in highly specialized regions and companies, its feats made possible by supply chains of exceptional length and complexity — a poster child, in other words, for globalization. "It's hard to imagine how the capabilities they've reached would be

possible without access to the smartest minds in the world all working together," Miller says. And yet it is this same interconnectedness that makes the industry vulnerable to regulations like those the Biden administration is pursuing.

Only a small handful of companies can compete at the cutting edge, where breakthroughs cost billions of dollars and decades of research. The result is an industry structured as a series of choke points. The best-known example is the extreme ultraviolet (EUV) lithography machine made by ASML, a Dutch manufacturing conglomerate, which is used to print out the layers of a chip. In 1997, ASML hired Jos Benschop, a young engineer with a Ph.D. in physics, to spearhead the creation of a new system, one that would help ASML's customers in the semiconductor industry print smaller, faster and denser chips than ever before. It took four years to achieve the proof of concept necessary to even justify assigning a small team to the task, and then another five years for the team to build a prototype machine. In December 2010, at a research facility in South Korea, an updated prototype, a TWINSCAN NXE:3100, finally had its first successful test run. It would be nearly another decade before the first EUV-enabled products would go to market.

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complex thing mankind has ever produced.'

The newest version of the machine can craft structures as small as 10 nanometers; a human red blood cell, by comparison, is about 7,000 nanometers across. It uses a laser to create plasma 40 times hotter than the surface of the sun, which emits extreme ultraviolet light — invisible to the human eye — that is reflected onto a silicon chip by a series of mirrors. The laser is sourced from a German company and has 457,329 pieces; an entire EUV has more than 100,000 components of similar intricacy.

An EUV is just one part of the process: A cutting-edge fab can include more than 500 machines and 1,000 steps. And yet an EUV alone is a nearly miraculous human achievement, capable of working at scales and precisions that are difficult to fathom. "I truly believe our machine is the most complex thing mankind has ever produced," says Benschop, now ASML's corporate vice president of technology. Today, more than a decade since the TWINSCAN's first test run, no other company has been able to recreate ASML's achievement.

By squeezing on the industry's natural choke points, the Biden administration aims to block China from the future of chip technology. The effects will go far beyond cutting into

Chinese military advancements, threatening the country's economic growth and scientific leadership too. "We said there are key tech areas that China should not advance in," says Emily Kilcrease, a senior fellow at the Center for a New American Security and a former U.S. trade official. "And those happen to be the areas that will power future economic growth and development." Today, scientific advances are often made by running simulations and analyzing huge amounts of data, rather than through trial-and-error experiments. Simulations are used to discover new lifesaving drugs, to model the future of climate change and to explore the behavior of colliding galaxies — as well as the physics of hypersonic missiles and nuclear explosions.

"The person with the best supercomputer can do the best science," Jack Dongarra, founding director of the Innovative Computing Laboratory at the University of Tennessee, told me. Dongarra runs a program called the TOP500, which offers a biannual ranking of the fastest supercomputers in the world. As of June, China claims 134 spots, compared with 150 for the U.S. But the picture is incomplete: Around 2020, China's submissions plummeted in a way that suggested to Dongarra a desire to avoid attracting unwanted attention. Rumors of new supercomputers leak out in scientific papers and research announcements, leaving observers to guess at the true state of the competition — and the size of China's presumed lead. "It's striking because

in 2001 China had no computers on the list," Dongarra says. "Now they've grown to the point that they dominate it."

Yet beneath China's strength is a crucial vulnerability: Nearly all the chips that power the country's most advanced projects and institutions are inexorably tied to U.S. technology. "The entire industry can only function with U.S. inputs," Miller says. "In every facility that's remotely close to the cutting edge, there's U.S. tools, U.S. design software and U.S. intellectual property throughout the process." Despite decades of effort by the Chinese government, and tens of billions of dollars spent on "indigenous innovation," the problem remains acute. In 2020, China's domestic chip producers supplied just 15.9 percent of the country's overall demand. As recently as April, China spent more money importing semiconductors than it did oil.

America fully grasped its power over the global semiconductor market in 2019, when the Trump administration added Huawei, a major Chinese telecommunications maker, to the entity list. Though the listing was ostensibly punishment for a criminal violation — Huawei had been caught selling sanctioned materials to Iran — the strategic benefits became immediately obvious. Without access to U.S. semiconductors, software and other essential supplies, Huawei, the largest telecommunications-equipment producer in the world, was left struggling to

survive. “The Huawei sanctions immediately pulled back the curtain,” says Matt Sheehan, a fellow at the Carnegie Endowment for International Peace who studies China’s tech ecosystem. “Chinese tech giants are running on chips that are made in America or have deep American components.”

Export-control law had long been seen as a dusty, arcane backwater, far removed from the actual exercise of American power. But after Huawei, the United States discovered that its primacy in the semiconductor supply chain was a rich source of untapped leverage. Three firms, all located in the U.S., dominate the market for chip-design software, which is used to arrange the billions of transistors that fit on a new chip. The market for advanced chip-manufacturing tools is similarly concentrated, with a handful of companies able to claim effective monopolies over essential machines or processes — and nearly all of these companies are American or dependent on American components. At every step, the supply chain runs through the U.S., U.S. treaty allies or Taiwan, all of them operating in a U.S.-dominated ecosystem. “We stumbled into it,” Sheehan says. “We started using these weapons before we really knew *how* to

use them."

In May 2020, the Trump administration tightened the screws further, this time by making Huawei subject to a formerly obscure provision of export-control law called the foreign direct product rule. Under the F.D.P.R., foreign-made items are subject to American controls if they were produced using American technology or software. It is a sweeping assertion of extraterritorial power: Even if an item is made and shipped outside the United States, never once crossing the country's borders, and contains no U.S.-origin components or technology in the final product, it can still be considered an American good.

For Huawei, the application of the F.D.P.R. meant the company was virtually cut off from semiconductors. "That rule subjected all semiconductors on the planet to American law, because every foundry on the planet uses U.S. tools at least in part," Kevin Wolf, a former assistant secretary of commerce for export administration at the B.I.S., says. "If you have one U.S. tool and 100 non-American tools in your fab, that taints any wafer moving across the line."

In 2020, according to the market-analysis firm Canalys, Huawei was the largest smartphone seller in the world, with an 18 percent market share, besting even Apple and Samsung. Huawei's revenues plunged by nearly a third in 2021, and the company sold off one of its smartphone

brands in a bid to stay afloat. By 2022, its share had fallen to 2 percent.

The Oct. 7 rules represented the sum of everything U.S. policymakers had learned about semiconductors, supply chains and American power. The measures were announced as an "interim final rule," meaning they took effect immediately — a direct reaction to a perceived weakness in the Huawei controls. "There was a lot of notice before the Huawei rule came into effect, and they spent the time beforehand stockpiling," says Peter Harrell, a former senior director for international economics at the National Security Council who was involved in crafting the Oct. 7 rules. "That was a tactical lesson — that you need the element of surprise." More important, the United States had learned that hobbling one company, however large, simply created room for new competitors to step in. A more comprehensive approach would be needed. "The Trump administration went after companies," says Allen, the CSIS expert. "The Biden administration is going after industries."

The rules went deeper into the semiconductor supply chain than any previous measure. China was cut off not just from importing the most advanced chips, but also from acquiring the inputs to develop its own advanced semiconductors and supercomputers, and even from the U.S.-origin components, technology and software that could be used to produce

semiconductor-manufacturing equipment to eventually build their own fabs to make their own chips. “It was an ‘all of the above’ strategy,” Wolf, the former B.I.S. official, says. Some elements were entirely novel, like a restriction on the activity of any “U.S. persons” — companies and citizens, as well as green-card holders and permanent residents. After Oct. 7, U.S. persons are no longer allowed to engage in any activity that supports the production of advanced semiconductors in China, whether by maintaining or repairing equipment in a Chinese fab, offering advice or even authorizing deliveries to a Chinese semiconductor manufacturer.

The decision to act unilaterally was a diplomatic gamble. Though the United States controls a number of key choke points in the global supply chain, other countries — particularly Taiwan, Japan and the Netherlands — hold dominance over similarly crucial sectors of the manufacturing process. Had those countries continued to sell to China as before, it would have rendered the Oct. 7 controls nearly useless. But in late January, the Biden administration reached an agreement with Japan and the Netherlands, under which they would implement similar controls on semiconductors or semiconductor-manufacturing equipment.

Taiwan had already signed on months earlier, as soon as the controls were announced. The island is a chip-

manufacturing juggernaut: It produces almost two-thirds of the world's semiconductors annually, and over 90 percent of the most advanced ones. Much of that output is thanks to a single firm, TSMC, the most valuable public company in all of Asia and the most advanced semiconductor manufacturer in the world. By itself, TSMC accounts for about a third of the total global market for contract chip fabrication. (OPEC, by comparison, controls about 40 percent of the global oil market.)

> ***'At some point, you're replicating all of human civilization.'***

Taiwan's central role in global chip production makes it indispensable to the United States. If the island's fabs were to be captured by China, or knocked offline during an invasion, the costs to the global economy would be catastrophic. Taiwan's chips stranglehold is sometimes called its "silicon shield" — the island's most formidable deterrent against a Chinese attack, and its best assurance of American help in the event of a Chinese invasion.

But the partnership between the U.S. and Taiwan is an unequal one. Though Taiwan is unmatched in chip manufacturing, it captures less than 10 percent of the global

market by revenue. The bulk of sales — 40 percent in 2022 — go to the American firms that export their chip manufacturing to Taiwan, in much the same way that American clothes designers profit from the sale of items that are actually sewn overseas. Strategically, American policymakers see the U.S.'s dependence on Taiwan as an unacceptable risk. They have pushed for TSMC to build more fabs in the U.S., as part of a broader strategy to locate more semiconductor manufacturing closer to American shores.

Taiwan has no choice but to comply, for fear of upsetting its most powerful ally and largest arms supplier; but with every move to erode the island's pre-eminence, it makes itself more vulnerable. In the worst case, Taiwan's chip chokehold may only invite more destruction: Some American commentators and war-gamers have suggested that, if China does invade, the U.S. should destroy TSMC's fabs to stop them from falling under China's control.

One problem with trying to control the global flow of semiconductors is that they're very small, lightweight and valuable. "Smugglers love stuff like that," Allen says. But China needs chips in large quantities to power massive data centers and facilities housing cutting-edge computers — and that makes their procurement uniquely challenging. "Those are large buildings, and they don't move," Miller says.

"It's uniquely suited to be understood by U.S. intelligence." The structure of the market will also present a hurdle to anyone trying to circumvent the regulations: The number of companies capable of producing cutting-edge chips is extremely limited, and the number of buyers with a history of purchasing from them is also small.

But there are also loopholes in the enforcement system, which Chinese companies are already probing. In March, Inspur Group, a Chinese conglomerate active in cloud computing and server manufacturing, was added to the entity list. But according to The Wall Street Journal, at least one of the company's affiliates was not included in the listing, allowing American businesses to sell to the subsidiary unimpeded.

Chips are moving through China by more circuitous routes as well. Last month, Reuters reported on a booming underground trade in high-end chips in Shenzhen, with multiple retailers touting their ability to supply the A100, a powerful chip made by the American company Nvidia. The U.S. government's ability to detect and prevent these types of hand-to-hand sales is limited: B.I.S. has only three enforcement agents stationed in China. But the existence of the underground market was, in fact, an early signal of the controls' efficacy. According to retailers interviewed by Reuters, the chips were available only in small batches,

perhaps from stocks shipped to China before the ban took effect. “It highlights that the controls are working,” an industry executive, who requested anonymity in order to candidly assess American policy, told me. “They wouldn’t be doing that if chips flowed freely.”

The battle over the controls may serve as a kind of civilizational test. In the West, the onus of compliance will fall largely on private companies. “Industry is our primary line of defense,” says Thea Rozman Kendler, the assistant secretary of export administration at B.I.S. “We can do whatever we can in government to promulgate clear and concise and effective rules, but it’s industry that’s responsible for compliance and putting those rules into effect.” For the controls to succeed, American industry will need to engage in actions that are, at least in the short-term, self-sabotaging, shutting off a piece of the lucrative Chinese market. Companies will have ample reason to operate as close to the edge of legality as possible, and their Chinese counterparts will have every incentive to game the system and feed them the information needed to approve a sale.

For China, the race for technological self-sufficiency presents perhaps a greater challenge than any the country has faced. The very traits that make China’s success possible — iron political will, endless money and a whole-of-society mobilization around key goals — are just as likely to

prove its Achilles' heel. In the last several years, as the push to develop a domestic semiconductor industry has taken on new urgency, at least six multibillion-dollar chip projects have failed and a number of executives have been put under investigation for corruption. Tens of thousands of companies, meanwhile, have flooded into the semiconductor industry, some of them with little or no expertise in chips, solely in search of easy government money.

"It's easy for political leaders or executives to think if we throw enough money and engineers at this problem, we'll solve it," Jason Matheny, former deputy director of the White House Office of Science and Technology Policy, says. But the immense complexity of the science and the globe-spanning supply chains are difficult to imitate. "At some point," says Matheny, "you're replicating all of human civilization."

Yet if any country can overcome such a challenge, it is likely to be China. The Oct. 7 export controls, while crippling China's advanced chip-making ability for the foreseeable future, may end up spurring long-term growth. When Chinese companies had access to superior Western chips and suppliers, domestic manufacturers struggled to find business. Now Chinese companies must innovate together or die. "We've removed choice," Kilcrease says. "Before they could choose between national resiliency and commercial

motivations, and now they don't have that choice." Should a large share of China's $400 billion in annual chip imports be turned inward, domestic chip companies may finally have the means and motivation to catch up.

Huawei may prove instructive once again. Battered by American sanctions and China's strict pandemic controls, the company's 2022 profits fell by a staggering 70 percent compared with the previous year. But there are signs of life: Despite the plunge in profits, revenues rose slightly, and the company's operating system, HarmonyOS — which it developed after being cut off from using Android — has been installed on more than 330 million devices, mostly in China. Huawei remains one of the world's biggest spenders on research and development, with a budget of about $24 billion last year and a research team of over 100,000 employees.

The emphasis on innovation is by necessity. Bereft of American chips and technology, Huawei has been forced to redesign and remanufacture all of its legacy products to ensure they contain no American components. The company is dragging along an entire domestic supply chain in its wake, sending its own engineers to help train and upscale Chinese suppliers it once shunned in favor of foreign alternatives. Recently, Huawei claimed that it had made significant breakthroughs in the electronic design software

used to produce advanced semiconductors at a size that, though still a few generations behind the U.S., would put it further along than any other Chinese company. If Huawei manages to succeed, it could emerge from American sanctions stronger and more resilient than ever.

The controls will not stop China permanently. Even in the best case, they're a delay tactic, meant to offer the U.S. and its allies space to expand their lead in key technologies. The question is how much time B.I.S. can buy for the West. "This isn't the type of business where success is batting one thousand," said Matt Axelrod, the assistant secretary for export enforcement. "Our goal is to stop as much as possible."

I was meeting with Axelrod and Rozman Kendler, the export administration chief, at the Commerce Department building, in an office overlooking the Ellipse in downtown Washington, D.C. It had taken just a few minutes to walk nearly the entire length of B.I.S.'s headquarters. Even allowing that enforcement need not be perfect, I wondered whether this was a fair fight — the Bureau of Industry and Security versus the full weight of the Chinese government. How could B.I.S. win? How could it hope to move as quickly? How could B.I.S. possibly put as much money behind the effort, and care as much about chips as China does? The future of chips was life or death for China.

There were a few seconds of silence before Rozman Kendler answered, in a quiet voice. “It’s probably life or death for us too,” she said.

Alex W. Palmer is a contributing writer for the magazine. He last wrote about the rise of TikTok. **Grant Cornett** is an artist who resides in the Catskill Mountains. His work focuses on objects and their relation to light and time in natural settings and more composed commercial projects.

A correction was made on

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An earlier version of this article misidentified the way in which extreme ultraviolet light is manipulated during the manufacturing of semiconductor chips. EUV is reflected, not refracted, during the process.

A version of this article appears in print on July 16, 2023, Page 30 of the Sunday Magazine with the headline: Inside the Biden administration’s brazen, high-stakes battle with China over semiconductors.. Order Reprints | Today’s Paper | Subscribe