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COVER STORY

The Titan of Taiwan

With attacks from China and pressure from the U.S., can TSMC maintain its edge?

BY TIM DE CHANT — JUNE 13, 2021

Illustration by Sam Ward

Sometime in the fall of 2019, IT staff at an unnamed semiconductor firm in Taiwan noticed a user's account behaving oddly. Concerned, they called Benson Wu, who runs a cybersecurity firm in New Taipei City, to help investigate.

Wu and his team at CyCraft began probing the network of the company, and they confirmed the IT staff's suspicions: the firm had been hacked. Eight accounts and 24 computers had been compromised, giving the attackers broad access to the company's network and files.

In many cases, it might have ended there. The company's IT group might have wiped the infected computers, rooted out the compromised accounts, and moved on. But what Wu found unsettled him. The attackers' tactics matched those of another intrusion staged against one of his longtime clients, also a vendor in the semiconductor industry. The difference was, with this company, the attackers had been inside the network for over a year.

The attackers had crafted a piece of malware, or malicious software, that looked like an update to Google's Chrome web browser. Once the malware was injected into a computer, it pinged servers hosted on Google's cloud and awaited instructions. Because the malware was communicating with Google servers, the attackers slipped into the company's network undetected time and again, siphoning sensitive and confidential data out.

As Wu and his team watched the attackers at work, they noticed a bit of data used to authenticate the attackers' communications channels. This allowed Wu to slip into the attacker's servers where he discovered a "quick start" guide for the malware written in simplified Chinese, the script used on mainland China but not Taiwan. Over time, Wu also noticed the adversaries worked a "996 shift" — 9 a.m. to 9 p.m. Beijing time, six days a week — which is a hallmark of the Chinese tech industry, and they were absent on mainland Chinese holidays.

TSMC produces more than half of the world's semiconductors.
Credit: Taiwan Semiconductor Manufacturing Co., Ltd.

For Wu, the fact that the attackers were likely from the People's Republic of China — which has, in recent years, been desperate to develop its own semiconductor industry — wasn't exactly surprising.

"Taiwan only has one cyber enemy," says Wu. "These kinds of organized operations, you wouldn't see them decades ago. There are ten different organizations that are targeting Taiwan, and they are all state-sponsored."

Indeed, as a recent report from the Information Technology and Innovation Foundation, a Washington-based think tank, notes, "The acquisition of foreign semiconductor technology through IP theft has been an essential pillar of Chinese strategy to develop its semiconductor industry." And for China's semiconductor goals, few targets are as rich as Taiwan. In less than 40 years, the small, self-governed island has transformed its economy into a technological powerhouse; its chip companies are now the envy of the world. Its crown jewel, TSMC, owns nearly 30 percent of all contract semiconductor manufacturing capacity, more than double its nearest competitor. By revenue, it's even more dominant, capturing over 50 percent of all revenue in the market. That distortion is due, in large part, to the company's prowess at the leading edge — TSMC produces around 90 percent of the world's most advanced chips, which gives it access to considerable profits which enable its R&D efforts.

When analysts talk about China's attacks on Taiwan's semiconductor industry, they often mean TSMC. For years, China has poached employees from TSMC, and China's national champion, SMIC, has been accused of stealing TSMC's intellectual property. Although Wu says Taiwanese companies are not required to disclose cyber attacks, TSMC did report being hit by the WannaCry malware attack in 2018 — which is widely believed to have been organized by North Korean hackers who operated at least part-time in China.

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>
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Given Taiwan's dominance in the semiconductor industry as well as its longstanding tension with mainland China, analysts say the island has become a kind of cyber crucible. "Taiwan is probably the target of more cyber attacks than anyplace else in the world on a daily basis," says Bonnie S. Glaser, director of the Asia Program at the German Marshall Fund of the United States. "Hopefully TSMC has been protecting its IP. It's important to Taiwan, but also so many other countries."

TSMC, for its part, has tried to maintain a low profile, but China's increasingly brazen attempts to pilfer Taiwan's semiconductor industry have highlighted for Western observers how vulnerable the supply chain is for this crucial technology, which powers everything from cars to smartphones. A recent White House report, for example, notes that "a disruption in the production of logic chips at foundries in Taiwan could result in nearly $500 billion in lost revenues for electronic devices manufacturers that depend on this supply." The United States, the report goes on to note, "is heavily dependent on a single company — TSMC — for producing its leading edge chips."

Thanks to the recent global chip shortage and an increasingly fraught U.S.-China relationship, the American dependency on TSMC has forced the company to the forefront of geopolitics. In the past year, the company has gained notoriety as one of the main pressure points in the longstanding tensions between the U.S., Taiwan and China.

A sudden supply chain shock could have a far-reaching and unforeseen impact in any of these areas, not only for specific industries, communities, and workers, but also potentially affecting national security and critical infrastructure. For example, SIA estimates that a disruption in the production of logic chips at foundries in Taiwan could result in nearly $500 billion in lost revenues for electronic devices manufacturers that depend on this supply.[13]

In summary, while U.S. production capacity has been stable, the United States lacks sufficient capacity on a relative basis to produce semiconductors and relies extensively on sources in Taiwan, South Korea, and China for production. The United States is heavily dependent on a single company–TSMC–for producing its leading edge chips and has significant dependence on China for mature node logic chips. Since semiconductors are such key components, the fragile supply chain for semiconductors puts virtually every sector of the economy at risk of disruption. Recent events affecting global supply chains, such as the COVID-19 pandemic, weather-related events, and the blockage of the Suez Canal demonstrate the importance of preparedness and supply chain resilience. The lack of domestic production capability also puts at risk the ability to supply current and future national security and critical infrastructure needs. U.S. production is also threatened by significant Chinese investments to expand its chip production capability and a greying of the U.S. workforce.

Credit: The White House

"All these elements converge, and TSMC emerges as a super important company," says Rupert Hammond-Chambers, president of the U.S.-Taiwan Business Council. "They have always been an important company, but before, they played no role in public policy. Now, TSMC is not just the biggest company in Taiwan, but potentially a pawn in the global game."

As the global spotlight has fallen on TSMC, most of the attention has focused on the company's efforts to expand operations in countries like the U.S. and Japan as well as its impressive technological feats and market share. Just this month, the firm said it had started construction on a $12 billion chip fabrication facility, or "fab," in Phoenix, Arizona. And at the end of last year, the New York Stock Exchange-listed company surpassed $500 billion in market capitalization; it has since reached $560 billion, making it the world's 11th-most-valuable company.

But the 34-year-old firm's rise wasn't preordained.

"All of a sudden all these people are saying, 'Oh my god, they're so far ahead.' That didn't happen overnight," says Willy Shih, a professor at Harvard Business School. "That came from investing billions of dollars year after year after year. They've been very smart about it, very thoughtful about it, and very methodical."

In fact, it wasn't clear until a few years ago that TSMC had pulled so far ahead of the pack. To hit that inflection point, TSMC needed a deep-pocketed partner to help it master ever more advanced manufacturing techniques. Few companies have that kind of money to spend on custom chips, and at the time, most of those who did were already TSMC customers. The only one that was not was Apple.

'A WONDERFUL DINNER'

It was 2010, and TSMC's founder and CEO, Morris Chang, had invited Apple's vice president of operations, Jeff Williams, to his home in Taiwan for dinner. This wasn't just a friendly gesture — Chang wanted Apple's business. Apple had recently embarked on a new phase in the company's history, developing its own microprocessors to serve as the brains behind the iPhone, iPad, and, eventually, the Mac. At the time, sales of the iPhone were taking off, and Chang saw an opportunity.

It was a bold move. Apple had been sourcing its chips from Samsung for years. In 2006, the Korean company started making chips for Apple's iPod line, and when the iPhone came out, Samsung-made processors were inside that, too.

"Customers become very attached to the manufacturers of their chips. It is a symbiotic, cooperative relationship," says Hammond-Chambers. "Trust is so important."

Under other circumstances, Williams may not have even accepted Chang's dinner invitation. But Chang's timing was right. Apple's trust in Samsung had been eroding ever since the conglomerate introduced a series of Android-based phones that looked strikingly similar to Apple's flagship product. Though a different Samsung division made Apple's chips, the California company was not thrilled to be funding a competitor, even indirectly.

Morris Chang, chairman and founder of Taiwan Semiconductor Manufacturing Company Ltd. (TSMC), speaks at the company's annual general meeting in Hsinchu, Taiwan, on Tuesday, June 9, 2015. Chang expects sales to rise at least 10 percent this year.
Photographer: Billy H.C. Kwok/Bloomberg via Getty Images

So, Williams flew to Taiwan, and the pair, joined by Chang's wife, had a "wonderful dinner," as Williams recalled in a 2017 speech for TSMC's 30th anniversary.

"We were not doing business with TSMC at that time, but we had a great conversation. We talked about the possibility of doing stuff together, and we knew the possibilities were great if we could take leading-edge technology and marry it with our ambitions."

A few months after the dinner, Apple reportedly offered to invest in TSMC, or at least pay a hefty sum to reserve fab space for Apple's chips. But Chang demurred, preferring to keep his company's hard-won independence. It wasn't until 2013 that the two companies signed a deal. The first TSMC-made Apple chip debuted in 2014, in the iPhone 6, with production split with Samsung. But by the time the iPhone 7 rolled around in September 2016, Apple was all in on TSMC.

"Apple's decision to contract with TSMC was a major turning point in the fortunes of both companies," says Timothy R. Heath, a senior researcher at the RAND Corporation. "It turned out to be a brilliant move that really energized Apple and TSMC."

Since 2015, the company has sold around 1.2 billion iPhones and around 300 million iPads. That's nearly 1.5 billion chips that TSMC has sold to Apple across just two product lines. Those sales have helped bankroll TSMC's substantial research and development budget, accelerating the company's ability to make more powerful and efficient chips with ever smaller transistors. Today, only Samsung comes close to replicating TSMC's manufacturing prowess at the leading edge, but even they can't match TSMC's capacity.

Apple Inc COO Jeff Williams, left, and Morris Chang, right, during a panel discussion to celebrate TSMC's 30th Anniversary.
Source: Twitter

None of this would have been possible if Chang hadn't embraced the foundry model to its fullest. Before Chang founded TSMC, most — if not all — semiconductors were made by the companies that designed them. People in the field call these companies "integrated device manufacturers," or IDMs. Texas Instruments, where Chang worked in the 1960s and '70s, and Intel are famous IDMs, designing chips that they make in their own fabs. American firms were proud of their design chops, and owning a fab was a point of pride. As AMD's cofounder once said, "Real men have fabs."

Yet in the late 1970s, researchers began to push for the idea of separating design from manufacturing. Carver Mead, a researcher at Caltech, didn't want to build and maintain an expensive lab to make the chips he was dreaming up, so he went looking for someone to make them for him. "At the time," Mead said in a 2007 interview, "nobody did it that way. And there was huge, huge resistance to the thought that there could be a new way."

American companies passed on the idea, but Chang — who was born in Ningbo, China and became an American citizen after attending MIT for his undergraduate studies and Stanford for graduate school — was recruited to work in Taiwan as president of the government's Industrial Technology Research Institute, which was exploring Mead's concept. At the time, Taiwan was "looking for the next big thing," says Shelley Rigger, a professor of political science at Davidson College. "Chang could have built it in the U.S., but America doesn't do that. So Taiwan put him to work."

In the mid-1980s, Taiwan did not have much expertise in chip design, almost no experience selling or marketing complex computer chips, and very little intellectual property around circuit designs. "The only possible strength that Taiwan had — and even that was a potential one, not an obvious one — was semiconductor manufacturing, wafer manufacturing," Chang said in a 2007 interview. "And so what kind of company would you create to fit that strength and avoid all the other weaknesses? A pure-play foundry." With some funding from Philips, the Taiwanese government, and a few private investors, TSMC was founded in 1987.

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Over the years, TSMC began to accumulate high-profile customers, including Qualcomm, Broadcom, and even Intel, which sent some of its less profitable chips to the foundry. As TSMC gained customers and revenue, it continued to plow money into research and development, refining its technologies and advancing its manufacturing techniques.

"This has all happened incrementally and quietly under the radar," says Paul Triolo, practice head for geotechnology at Eurasia Group. "But Morris Cheng was a visionary in the sense that he developed this horizontal, symbiotic model between TSMC and design companies that has allowed TSMC to master very sophisticated technologies and rise above other manufacturers."

For 30 years, TSMC was a relatively anonymous supplier. While Intel flooded the airwaves with its five-note jingle, TSMC did nothing of the sort. They preferred their low profile.

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'EVERYONE WANTS ONE'

TSMC didn't become a household name until the Covid-19 pandemic descended on the world and caused a global chip shortage.

When governments locked things down, everyone steeled themselves for a long and protracted economic contraction. Restaurants closed, businesses laid off workers, and automakers, scarred by the Great Recession, immediately slashed orders with their suppliers.

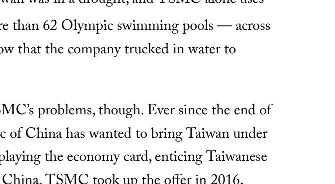
Yet the semiconductor industry hardly skipped a beat as quarantined people ordered piles of laptops and tablets. Semiconductor fabs were running at full capacity, despite the lost orders from automakers and other companies.

Then, just months after lockdowns began, people started buying new cars again, far earlier than car companies expected. Existing chip inventories quickly vanished. Semiconductor manufacturing capacity, which had already been tight, was squeezed to the max.

The chip shortage underlined semiconductors' importance in today's economy. Governments around the world, fresh off their struggles securing N95 masks, grew concerned with the concentration of semiconductor manufacturing in Asia — particularly in Taiwan and particularly with TSMC. Elected officials and military brass alike suddenly realized just how dependent they were on an island that's both geographically and geopolitically vulnerable.

"Taiwan is subject to lots of natural disasters — drought, earthquakes, typhoons," says Triolo. Indeed, for much of the last year, Taiwan was in a drought, and TSMC alone uses 156 million liters of water per day — more than 62 Olympic swimming pools — across its three main sites. Reservoir levels got so low that the company trucked in water to ensure a supply.

Natural disasters are perhaps the least of TSMC's problems, though. Ever since the end of the Chinese Civil War, the People's Republic of China has wanted to bring Taiwan under its rule. In recent decades, Beijing has been playing the economy card, enticing Taiwanese companies to set up operations in mainland China. TSMC took up the offer in 2016, breaking ground on a fab in Nanjing, and over the years, as China's indigenous semiconductor companies have designed more sophisticated chips, they've turned to TSMC to make them in their latest and greatest fabs.



TSMC 12-inch Wafer Fabs.
Credit: Taiwan Semiconductor Manufacturing Co., Ltd.

But all that came to a halt when the Trump administration blocked Huawei, the Chinese telecom giant, from buying chips made with U.S. equipment. American semiconductor firms have about 50 percent of the global market, and they're hard to avoid. TSMC uses software, tools, and equipment from a range of American companies, including Applied Materials, IBM, and Lam Research, along with EUV scanners from ASML, a Dutch company that sources key parts from the United States. TSMC had no choice but to stop sales to Huawei.

"This whole incident has highlighted China's dependence on TSMC and their vulnerability to losing access," says RAND's Heath. "What China wants is to regain access to those chips, and there are multiple options for it to do so."

One option is to squeeze Taiwan with economic coercion. Despite the Huawei ban, TSMC still gets about 6 percent of its revenue from China — revenue that observers say TSMC would prefer to maintain.

"They will basically work their best to make sure that they can continue selling to some kind of customers in China," says Segal.

That may not be an option, though, if U.S.-China tensions continue to rise. "While China is a strong growth customer," says Hammond-Chambers, "the biggest customer by miles is the United States. They know where their bread and butter is." And, Heath adds, "there's no guarantee that economic coercion would work. It may just poison the well, making Taiwan less likely to sell those chips."

China could use other means, of course, including force. Though an invasion of Taiwan would probably take place for other reasons — nationalist sentiment chief among them — analysts routinely point out that the world's most advanced semiconductor manufacturer lies just 110 miles from mainland China.

Still, none of the sources that spoke with *The Wire* thought hostilities were imminent. "A large-scale invasion is very unlikely," says Segal. "More likely is a blockade or an announcement of some military exercises that would signal China's seriousness about using force."

And far from being a prize of war, TSMC may be a deterrent to hostilities. For one, TSMC's fabs could be badly damaged in the fighting. Even if they weren't, the fabs operate using hardware and software made by companies from myriad countries that would not look kindly upon a Chinese invasion of Taiwan. Support for those key assets would almost certainly be cut off.

"In order for TSMC to be as successful as it is, it needs to remain deeply integrated into many Western economies. The moment China conquers Taiwan and tries to grab it for itself, TSMC will quickly lose a lot of its value," says Heath.

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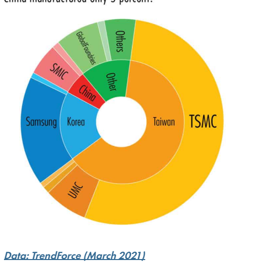
Taken together, the costs of gaining access to TSMC's manufacturing prowess through invasion would be spectacularly high. "If I were Xi Jinping," notes Rigger, "I would definitely spend all my money on espionage and domestic development before I would take the risk and pay the cost of trying to get a TSMC fab through military invasion."

So far, that appears to be what China is doing. When Benson Wu and his colleagues at CyCraft discovered evidence of operations by Winnti, a sophisticated group of hackers widely thought to be from mainland China, on the networks of several Taiwanese semiconductor firms, they were witnessing an attempt by Chinese actors to steal industry secrets.

"There is a broad recognition that there are actors — in some cases, state-supported actors — that are trying to position their industry players in a favorable way without having to devote 18–20 percent of revenues to R&D," says Ian Steff, CEO of mySilicon Compass and former Assistant Secretary of Commerce in the Trump administration.

Perhaps because of the threat of cyberattacks, TSMC has taken a pretty radical approach to protecting proprietary information. "A lot of important trade secrets aren't recorded anywhere. They will just reside in the minds of people who came up with the processes or who are on a need-to-know basis," says Will Hunt, a research analyst at Georgetown's Center for Security and Emerging Technology. "There's a huge amount of tacit knowledge that you actually couldn't steal because it's not available to steal on a hard drive."



Data: TrendForce (March 2021)

That makes traditional espionage, as well as plain old talent acquisition, all the more attractive to China. Thanks to generous compensation packages, Chinese companies have poached thousands of engineers from Taiwanese semiconductor companies over the last decade. "There is a saying," says Wu, "whatever your salary is right now, change New Taiwan dollars to renminbi — that's like five-times the amount."

"The talent part of the equation is really important," notes Ashley Feng, a former researcher at the Center for a New American Security. "When people think of IP and tech as a whole, they think of the actual patent. What they don't think of is the technical process of IP. That process is what TSMC has a huge

grip on. It's not just the manufacturing, it's also the people they've been able to train to run these fabs as efficiently as they have."

To make recruitment easier, Chinese firms have covertly set up offices in Taiwan. Recently, for instance, in March, Taiwanese prosecutors announced that they were investigating Bitmain Technologies, a Chinese company that specializes in AI and blockchain chips. Prosecutors allege the company set up two companies solely to recruit more than 100 engineers. One of the companies was just blocks from TSMC headquarters.

"The people who get bought out almost don't feel any difference," says Wu, of the Chinese head hunting efforts. In response to widespread recruitment of engineers by Chinese firms, Taiwan's Labor Ministry recently banned all advertisements for jobs in mainland China, particularly for those in the semiconductor industry.

TSMC has dealt with this sort of espionage before, most notably in the early 2000s when a quality control program manager was caught feeding trade secrets to SMIC, a then-new Chinese foundry started by former TSMC executive Richard Chang. The state-backed startup also recruited 180 engineers from TSMC, instructing them to bring with them documents and secrets from the Taiwanese company.

Yet even if a Chinese semiconductor firm were to steal all of TSMC's current secrets, they wouldn't necessarily be on equal footing. The semiconductor industry is second only to biopharmaceuticals in terms of R&D-intensive industries, and TSMC has pledged to invest $100 billion in R&D and manufacturing over the next three years — a sum that will only help them pull further ahead.

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"They're not standing still as China is trying to catch up," notes Glaser.

Nor do they seem willing to play the pawn amid rising U.S.-China tensions. At the same time that TSMC is building its new fab in Arizona, it has expanded production at its plant in Nanjing, China — a move that will help appease the chip shortage currently hobbling China's massive manufacturing industry. And while the Arizona fab is slated to produce 5 nanometer chips — the current leading edge — it won't be live until 2024, at which point the leading edge will be 3 nanometer chips, which will be made only in Taiwan.

"Computer chips are like Frito chips," says Rigger, "they become a commodity pretty fast. You're constantly running just to outrun that — you can never rest. But most people would argue that the strength of TSMC is they have a frontier that's so far out ahead of everyone else that it's very hard to imagine them being overtaken. For the time being, everyone wants a TSMC fab."

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