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# Sematech: A public-private partnership for spurring domestic manufacturing[1]

David M. Hart
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## INTRODUCTION

Sematech, a public-private partnership that aimed to advance semiconductor manufacturing technology (from which its name was derived), attained "near-mythical status" as the savior of the U.S. chip industry in the face of ferocious Japanese competition in the late 1980s.[2] The story is inspiring, but a unique set of circumstances enabled Sematech's success. Moreover, that success was fleeting: passage of the CHIPS and Science Act in 2023 reflected a sense that the U.S. semiconductor industry needs saving, again.

Many policymakers with an interest in supporting clean manufacturing have taken inspiration from the Sematech experience, supporting industry consortia across a wide range of fields. But these consortia, operating in contexts very different from Sematech's, have not yet emulated its success. Looking forward, the emerging Chinese challenge to the U.S. auto industry provides the closest analogy to the semiconductor industry in the 1980s. Federal support for a consortium to respond to this challenge (or any others in clean manufacturing) might be conditioned on replicating some semblance of Sematech's notable attributes—organizational autonomy, savvy leadership, and unity of purpose across industry and government—and on the adoption of complementary trade and antitrust policies.

## THE RISE OF JAPANESE ELECTRONICS MANUFACTURING

The United States emerged from World War II as the undisputed global leader in the new field of electronics, and the early Cold War deepened this advantage. The defense sector supported the underlying science and technology for hardware, software, and networking. It was also an early, cost-insensitive adopter of these innovations. The federal government purchased about 40% of all semiconductor devices in the early 1960s, for instance, and a much larger share of integrated circuits, the most advanced devices.[3]

As Japan recovered from the war's devastation and sought to regain momentum toward modernizing its economy, the national government targeted electronics, among other industries. Electronics was attractive because of its potential for continued rapid growth and development as well as for exports. Japan's policies began to pay off in the 1970s as the civilian electronics market boomed and Japanese producers made substantial inroads globally.[4]

### The Formation and Evolution of America's Semiconductor Manufacturing Strategy

**1970s** Japan, on the road to recovery from WWII, makes inroads globally on electronics production.

**1986** Under the Reagan Administration, Japan and the United States reach a deal to restrain Japanese exports, raise the prices of Japanese semiconductors, and open the Japanese market to U.S. exports.

**1987** Sematech is born as a consortium of 14 U.S.-domiciled semiconductor firms, which together account for roughly 85% of the nation's chip manufacturing capacity. Launched with a $200 million annual budget, the new consortium aims to collaborate on manufacturing technology by building its own factory while sharing lessons learned with its members

**1992** Given corporate reluctance to share process knowledge with competitors and shifting Department of Defense priorities, Sematech revises its focus from building a factory to strengthening U.S. upstream equipment and material suppliers. In conjunction with trade policy, Sematech's efforts helped U.S. producers retake the lead in global market share in both semiconductors and semiconductor equipment by the early 1990s.

**1995** Sematech continues to evolve, deciding to forego federal support and admit foreign-headquartered companies to Sematech's membership. By 1995, Sematech's membership includes seven foreign firms.

**2002** International Sematech relocates to Albany, New York in 2002 and enters into a partnership with the state.

**2015** The Chinese government adopts "Made in China 2025," a plan that seeks parity with international competition in semiconductors.

**2020** The Trump administration imposes tariffs and tightened export controls that target China's semiconductor industry.

**2021** America's share of the global semiconductor manufacturing market falls to 12% in 2021 from 37% in 1990.

**2022** Congress provides $11 billion in federal funding for semiconductor R&D and $39 billion to attract semiconductor manufacturing facilities. Congress also introduces an investment tax credit for facilities that produce semiconductors and semiconductor manufacturing equipment.

## THE 1985 CRISIS AND THE 1986 TRADE DEAL

In the 1980s, electronics was far from the only advanced industry in which Japanese exports were cutting into U.S. market share. American leadership in autos, machine tools, and many other industries—even aerospace—seemed vulnerable. The prospect of "Japan as #1" (the title of Harvard professor Ezra Vogel's 1979 bestseller) triggered one of the defining policy debates of the 1980s.

For the U.S. semiconductor industry, the crisis came to a head in 1985, after a series of unsuccessful agreements with Japan. Sales dropped 20%, leading firms suffered "unprecedented losses," and several went under. Japan surpassed the United States in global semiconductor market share for the first time. Japanese firms were particularly successful selling dynamic random access memory (DRAM) chips, which many observers believed at the time to be the linchpin of long-run competitiveness.[5]

In response, U.S. semiconductor firms mobilized to protect the domestic market, initiating several lawsuits alleging that their foreign rivals were dumping products at unfairly low prices. The industry also pressured the Reagan administration to step in, which it did, filing an anti-dumping case of its own in December 1985. The case revealed a softening of the administration's free market principles and prompted negotiations between the two governments. By September 1986, Japan and the United States reached a deal that restrained Japanese exports and raised their prices, while promising to open the Japanese market to U.S. exports.[6]

## FORMING SEMATECH

Merely sheltering American producers from Japanese competition would hardly have been worthwhile unless U.S. firms used the breathing space to address their weaknesses. Japanese companies had shown that they could manufacture more efficiently than their American competitors, even on the same equipment, while also driving down the cost of each new generation of chips. Japan's *keiretsu* structure, in which companies that were linked vertically in a supply chain also shared common ownership and financing, seemed to be a key advantage. American chipmakers insisted on customized solutions from their suppliers, even as they pitted suppliers against each other to secure the lowest price. In contrast to the *keiretsu* model, this business culture impeded communication and cooperation. The Japanese also placed a premium on quality, whereas the Americans seemed willing to sacrifice quality to build chips that were faster or higher-performing.[7]


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IBM, an iconic American firm and the nation's largest semiconductor manufacturer, took a leading role in pushing for change. Senior IBM executives, aided by the fledgling Semiconductor Industry Association and heavyweights like National Semiconductor CEO Charles Sporck, canvassed their peers. Under extreme duress, the industry reached consensus on the need to collaborate on manufacturing technology and seek help from Washington. Knowledge-sharing would reduce duplicative R&D spending across firms, while also enabling standardization that would set the stage for quality improvement and cost reduction.[8]

The U.S. Department of Defense also weighed in. Since semiconductors were vital components in a wide range of military systems, DOD sought to ensure that domestic production was available to supply its needs. The Defense Science Board, comprised of eminent civilian experts, released a series of reports that drew attention to the vulnerability of the semiconductor supply chain. The Department of Justice, a longtime antagonist of IBM, gave its blessing to Sematech as well, accepting that its activities would be pre-competitive and would not constitute an unlawful restraint on trade.[9]

With industry and executive branch support, Congress moved to sweeten the pot for collaboration. A few members of Congress preferred that the Department of Commerce sponsor the initiative in light of semiconductors' dual-use role in civilian as well as military products. But DOD possessed a massive budget, long experience with the industry, and broader bipartisan support. Within DOD, DARPA, which was beginning to take on a wider array of dual-use technologies, was given charge.[10]

Sematech was officially born in August 1987 as a consortium of 14 U.S.-domiciled semiconductor firms that together accounted for roughly 85% of the nation's chip manufacturing capacity. The new organization had a sizeable $200 million annual budget, with half of its funding coming from members and half from DARPA. Sematech's mission was to restore U.S. competitiveness in semiconductor technology by strengthening core manufacturing competencies.

## SEMATECH IN ACTION

Sematech set out with a plan to introduce the next three generations of semiconductors in just five years. The organization would build its own factory or fabrication facility ("fab") to prove out new manufacturing processes and share what it learned with its members. And, in a real coup, Robert Noyce, the legendary co-inventor of the integrated circuit and co-founder of Intel, took the helm as Sematech's first CEO.[11]

Yet, even as Sematech was setting up its initial fab and becoming an operating entity, its patrons were moving on to a new agenda. Leading corporate members were reluctant to share hard-won process knowledge with less capable competitors. DOD worried more about application-specific integrated circuits than commodity DRAMs. The fab as originally envisioned was going to be very costly. Rather than focus so intently on the chip production process per se, Sematech shifted its attention upstream—to strengthening U.S. equipment and material suppliers. "This research focus potentially benefits all members," according to one analysis, "without threatening their proprietary capabilities..."[12]

While the slimmed-down fab ultimately hit its product milestones, "creating .35-micron circuit features on a 200 mm silicon wafer with American-made equipment" in December 1992, these chips were made as prototypes or demonstration runs, not to establish commercially-viable processes.[13] The collaboration between suppliers and manufacturers required to run the fab proved more important than its physical output.

In pursuit of its revised agenda, Sematech supported projects to develop new types of equipment, compared tool performance, and improved the use of equipment on-site, in its members' facilities. The consortium also worked to strengthen partnerships between suppliers and users, develop industry-wide standards and associated training, and infuse new methods for ensuring quality. Spanning all of these activities, Sematech convened a series of roadmapping exercises that eventually built a shared vision of the industry's direction and pace of progress.

> "SEMATECH STRENGTHENED PARTNERSHIPS BETWEEN SUPPLIERS AND USERS, DEVELOPED INDUSTRY-WIDE STANDARDS AND ASSOCIATED TRAINING, AND INFUSED NEW METHODS FOR ENSURING QUALITY. SPANNING ALL OF THESE ACTIVITIES, SEMATECH CONVENED A SERIES OF ROADMAPPING EXERCISES THAT EVENTUALLY BUILT A SHARED VISION OF THE INDUSTRY'S DIRECTION AND PACE OF PROGRESS."

In conjunction with trade policy, Sematech's efforts helped U.S. producers retake the lead in global market share—in both semiconductors and semiconductor equipment—by the early 1990s. In a recent review of Sematech's accomplishments, Charles Wessner and Thomas Howell also credit the consortium with narrowing the quality gap, improving yields, accelerating the product cycle, revitalizing domestic equipment manufacturing, and making corporate R&D more productive.[14]

## SEMATECH, TAKE 2: PRIVATIZATION AND INTERNATIONALIZATION

While laudatory accounts of Sematech end in the early 1990s, the consortium did not shut down, but rather morphed once again. One major shift was the industry's decision to forego federal funding. Ironically, this change came even as the incoming Clinton administration hailed Sematech as a model for other industries. Sematech's members saw the value of the consortium and were in a strong enough financial position to fund it fully on their own. At the same time, they were mindful of the strings that inevitably attach to federal support, even though DARPA had managed the program with a light touch.[15]

A second major shift, consistent with forgoing federal support, was the the consortium's decision to admit of foreign-headquartered companies to Sematech's membership. Despite the appearance of international competition, border-spanning corporate partnerships had proliferated across the chip industry. These tie-ups, many involving U.S.-based firms, reflected the industry's extreme complexity, capital-intensity, and risk. South Korean and Taiwanese firms, aided by Japan's voluntary export restraints, had entered the U.S. market in the late 1980s. Taiwan's TSMC, notably, invented the new "fabless" business model, in which "capital-light" chip design firms, often based in the United States, outsourced manufacturing. Sematech created the International 300 mm Initiative, which included seven foreign firms, in 1995. By 1999, Sematech was a fully-integrated global consortium that counted Hyundai and TSMC among its members.[16]

International Sematech relocated to Albany, New York in 2002, and entered into a partnership with the state. The move helped establish this region as a hub of semiconductor research. Sematech's presence and extensive collaboration with local universities and IBM helped attract Global Foundries, a major semiconductor manufacturer. Nonetheless, America's share of the growing global semiconductor manufacturing market fell from 37% in 1990 to 12% in 2021. (The market share of U.S.-headquartered firms, by contrast, remained well over 40%.)[17]

## SEMATECH'S IMPACT

Sematech made important contributions to the U.S. semiconductor industry's reversal of fortunes in the late 1980s and early 1990s. The consortium helped change the industry's culture by creating and sharing knowledge and standards that benefited the industry as a whole. It drafted roadmaps that aligned expectations and focused investment. It helped U.S. suppliers like Applied Materials and Lam Research sustain or establish positions of global leadership that they still hold today.[18]

Sematech's strategic flexibility lay at the core of its successes. Had the consortium stuck with its initial focus on mass-producing DRAMs—the rationale that helped secure Sematech's initial public support—it would have run head-on into new competition from South Korea and Taiwan on top of that from Japan. Ironically, the decline of the U.S. DRAM segment didn't undermine the entire domestic industry, as Noyce among others, had asserted.[19] Instead, U.S. producers, with Sematech's support, excelled in making the most sophisticated chips, like microprocessors. U.S. Memories, a consortium that targeted memory chip production, failed to get off the ground in 1990. U.S.-based Micron Technology, by contrast, remains a major player in the semiconductor market.[20]

The fact that its leaders were held in high regard and could engage directly with the senior executives, including the CEOs, of member companies helped underpin Sematech's strategic flexibility. Close communication with DARPA, access to DARPA's expertise, and DARPA's own autonomy were also key to the consortium's success.[21]

Of course, Sematech's record, even its heyday, was not unblemished. It made some bad bets and some of its initiatives flopped. More importantly, larger trends lessened its relevance. Exchange rates rebalanced. Japan's economic bubble burst. The Cold War ended. The Internet boom fueled the U.S. economy. An important factor for the semiconductor industry specifically was the rise of global value chains, particularly the fabless business model centered on Taiwan with American design partners, which shifted industry priorities away from national competitiveness. Chip consumption shifted even further to Asia, especially to China, as that country became the epicenter of global manufacturing, while massive government subsidies attracted investment abroad.[22]

## THE RISE OF CHINESE CHIP MANUFACTURING AND THE CHIPS AND SCIENCE ACT

In 2015, the Chinese government adopted "Made in China 2025," a plan that seeks parity with, if not dominance of, international competition in semiconductors. Twenty-first century China is far more of a geopolitical competitor to the United States than twentieth-century Japan ever was, and chips continue to be vital to military systems as well as to the civilian economy. Moreover, Taiwan has become the world's dominant producer of the most advanced chips, and its vulnerability to Chinese coercion raises the stakes further. The disruptions caused by the COVID-19 pandemic, which squeezed semiconductor manufacturers particularly and had major knock-on effects for auto manufacturers and other end-users, provided a vivid warning of the risks of losing control over this supply chain.

Competition with China has prompted the United States to revive semiconductor policy, expanding it far beyond its earlier responses to competition with Japan. Over the objections of the now-globalized industry, the Trump administration imposed tariffs and tightened export controls, and the Biden administration has built on these measures. In 2022, Congress added an $11 billion R&D program and, smashing taboos, a $39 billion fund to attract manufacturing facilities (the fund is further sweetened by a 25% investment tax credit). According to the White House, a year after the CHIPS and Science Act was signed into law, "companies have announced over $166 billion in manufacturing in semiconductors and electronics."[23]

## INSIGHTS FOR CLEAN MANUFACTURING POLICY

The Sematech model has been widely emulated. The Department of Energy, for instance, identifies five Manufacturing USA institutes, two research hubs, and two user facilities as "Consortia [that] use federal funding as a catalyst to bring stakeholders together to address process and technological challenges in specific technology focus areas." DOE recently renewed several of these consortia, is reviewing others, and is considering new starts.[24]

These organizations, though they may be quite valuable, are an order of magnitude smaller than Sematech, even without adjusting for inflation. They generally target emerging technologies and new markets, rather than core products of existing industries. They are chipping away at the margins or seeding virgin territory, not pressing a counter-offensive on a major battleground. The Photovoltaic Manufacturing Consortium (PVMC) is an exception that perhaps proves the rule. Founded by Sematech in 2011, PVMC sought to establish a new thin-film solar PV manufacturing paradigm in the United States, but few traces of it can be found today. Instead, Chinese firms, backstopped by government subsidies, dominate the solar PV industry.[25]

In Sematech's case, the power of the consortium model was enhanced by a number of complementary factors. The perceived crisis of the industry was deep enough to break old patterns. The number of firms involved was small enough that effective coordination was possible, and their senior executives were personally engaged in the effort. The industry was tied closely enough to national interests to prompt a substantial five-year federal commitment. Sematech's members and its sponsoring agency, DARPA, were willing and able to change the consortium's strategy as circumstances changed. Trade and antitrust policies complemented semiconductor technology policy. Nonetheless, once the crisis waned, the government's attention—with industry's approval—turned elsewhere. A robust industrial policy for semiconductor technology has had to be revived nearly from scratch a quarter-century later.

Clean energy manufacturing is an enormous and diverse field. Most of it is far from mature, so relatively few sectors within it share the key characteristics of the semiconductor industry in the 1980s. Fewer still are perceived across party lines to be vital to America's national interest and threatened by international competitors. The auto industry is the most obvious candidate, given the Chinese head start in electric vehicles, the industry's scale, and prior instances where the federal government has stepped in to support domestic auto manufacturing. It's worth noting that past federally-funded auto industry consortia have had only modest success.

Although tight analogies between clean energy manufacturing and Sematech may be rare, two more broadly applicable threads may be worth pulling from this episode. One is the relative autonomy that Sematech enjoyed, which gave it flexibility to devise, adjust, and pursue its strategy. Clean energy manufacturing consortia will need similar insight and ability to adjust to rapidly changing conditions, while maintaining the confidence of their sponsors as they do. A second thread concerns the importance of embedding consortia in a broader package of policies. Just as trade policy alone might not have made a difference without industrial policy, the opposite is likely also true. Focusing only on industrial policy without shaping market conditions may leave a manufacturing consortium with fewer, weaker, and less willing members.

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