

# Establishing a National Manufacturing Foundation

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## Summary

Emerging technologies developed in the United States are routinely scaled up overseas due to a lack of domestic engineering skills, manufacturing know-how, investment capital, and supply chains.<sup>1</sup> A new national initiative is needed to ensure that discoveries and inventions made in the United States are manufactured at scale in the United States. Such an initiative will create good-paying jobs, strengthen defense preparedness, and protect intellectual property (IP) created through federally funded research. Building a strong manufacturing base at home will also strengthen the domestic innovation cycle, as the knowledge gained through manufacturing supports process improvements and new product iterations.

Manufacturing cuts across multiple disciplines and the missions of multiple federal agencies, but no agency has the nation's long-term manufacturing success as its sole objective. We propose creation of a new agency—a National Manufacturing Foundation (NMF)—to address this gap. The goal of the proposed NMF is not to restore lost industries, but to rebuild our lost capabilities and capacities to build and scale up products in the United States.

Funding for the NMF should be at least five percent of the total annual federal research and development (R&D) budget, about \$150 billion in 2018.<sup>2</sup> Five percent for the NMF would be \$7.5 billion annually, appropriated as an increase in total funds, not as a carve out from existing funds.

The NMF would do the following:

- (1) **Engage with other federal S&T agencies** to set technology priorities, mature promising product and process technologies funded through other federal agencies, access relevant expertise, and coordinate funding to ensure that promising technologies receive full support from discovery and invention to commercial-scale domestic production.
- (2) **Invest in translational R&D** to help advance emerging technologies beyond the pilot stage. This would include awarding grants and contracts to U.S. universities and other research institutions to support translational engineering (not science) research and manufacturing process technologies common to multiple industrial applications. This would also include establishment of a series of Translational

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<sup>1</sup> Sridhar Kota and Thomas C. Mahoney, *Manufacturing Prosperity: A Bold Strategy for National Wealth and Security*, MForesight, MF-TR-2018-0302 (June 2018).

<sup>2</sup> American Association for the Advancement of Science, "Historical Trends in Federal R&D", n.d., <https://www.aaas.org/programs/r-d-budget-and-policy/historical-trends-federal-rd - National>. As of FY 2017, late-stage development, testing, and evaluation programs, primarily within the Department of Defense, were no longer counted as R&D.

Research Centers (TRCs) affiliated with universities. TRCs would focus on advancing technology and manufacturing readiness of emerging technologies in order to enable successful hardware start-ups and to transform research results to new products and processes manufactured in the United States.

- (3) **Build connections between hardware start-ups and other federal agencies**, especially the DOD, to support translational research in defense-critical technologies. This would include leveraging federal purchasing power and the federal government's role as a customer to help American companies procure financing for plants and equipment to establish and ramp up production of new technologies.
- (4) **Facilitate public-private partnerships to create Manufacturing Investment Funds (MIFs)**. These MIFs would fill gaps in existing venture-capital markets, providing sufficient funding for hardware start-ups to scale production in the United States beyond pilot plants.
- (5) **Support small and medium-sized manufacturers (SMMs)** through technical assistance and financial support: including loans, grants, loan guarantees, and tax incentives. As the foundation of manufacturing value chains and the geographic distribution of diverse industrial clusters, it is essential that SMMs have the capacity to upgrade equipment, train staff, and fully participate in Industry 4.0.
- (6) **Grow engineering and technical talent at all levels** by significantly increasing federally funded graduate fellowships in engineering for U.S. citizens, partnering with state and local governments to increase the number of four-year engineering technology degree programs and to expand successful apprenticeship and skills-training programs.

The NMF will not be able to fulfill its promise and achieve its objectives if inventions continue to be manufactured abroad. Therefore, recommend a binding rule that if the intellectual property for a product or process is developed based on federally funded R&D, then that product or process must be manufactured substantially (e.g., a 75% minimum value-add) in the United States, without any exceptions or waivers.

## 1. Introduction

Thanks in large part to decades of offshoring manufacturing, the United States has compromised its ability to realize the full potential of its tremendous investments in research and development (R&D). An increasing amount of corporate R&D is done abroad, closer to where most factories are now located.<sup>3</sup> Worse, products built on

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<sup>3</sup> Since 2000, R&D performed abroad by the foreign affiliates of U.S. corporations has more than doubled. Source: "Science & Engineering Indicators 2018: Appendix Table 4-17," National Science Board, January 2018, <https://nsf.gov/statistics/2018/nsb20181/data/appendix>.

federally funded R&D in advanced technologies (such as organic electronics and nanomaterials) are increasingly manufactured abroad. The erosion of important industrial centers throughout the United States—machine tools in Cincinnati, steel in Pittsburgh and Youngstown, furniture in North Carolina—has resulted in a loss of engineering skills, infrastructure, supply chains, and production know-how domestically, limiting the ability of U.S.-based manufacturers to build and scale new technologies.<sup>4</sup> Overseas manufacturing of products based on taxpayer-funded R&D essentially subsidizes foreign producers in creating jobs and wealth from American inventions. Because of these dramatic changes in the nation’s industrial base, it is difficult for the United States to establish—let alone lead—the industries of the future. The longstanding U.S. strategy of “invent here, manufacture there” is fast becoming “invent there, manufacture there”—a dangerous trend for our nation.

Restoring U.S. manufacturing leadership requires the public sector to step in to correct a market failure. Short-term profit incentives will drive the private sector to continue offshoring manufacturing (and R&D) as long as it is economically favorable. But because the societal benefits of domestic manufacturing (in the form of national wealth, jobs, and national security) exceed the concentrated benefits of offshore manufacturing (see Section 3.4), the U.S. government has a critical role to play in realigning incentives.

Unfortunately, the U.S. government is not well positioned to respond effectively. No single federal agency has the health of the nation’s manufacturing sector as its primary mission. Multiple agencies—Defense, Energy, Commerce, and others—have programs to support manufacturing.<sup>5</sup> But these programs are neither strategic nor coordinated, poorly funded (relative to the need), and have not been successful at arresting the decline in engineering and manufacturing capabilities to support domestic production of emerging technologies.

In 2018, MForesight, a federally funded advanced manufacturing research consortium, conducted a nationwide study of challenges facing the United States in developing and implementing advanced product and process technologies. An overarching recommendation in the resulting report, *Manufacturing Prosperity*,<sup>6</sup> is to establish a new agency, a National Manufacturing Foundation (NMF), tasked with (1) developing and

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<sup>4</sup> This collection of skills, production capacity, supply chains, and experiential know-how is known as the “industrial commons.” The ramifications of our lost industrial commons are addressed in: Gary P. Pisano and Willy C. Shih, “Restoring American Competitiveness,” *Harvard Business Review* (July–August, 2009).

<sup>5</sup> The Department of Defense has notably acknowledged risks posed by weakness in the domestic production base. See, e.g., U.S. Department of Defense, *Assessing and Strengthening the Manufacturing and Defense Industrial Base and Supply Chain Resiliency of the United States*, Report to President Donald J. Trump by the Interagency Task Force in Fulfillment of Executive Order 13806 (September 2018).

<sup>6</sup> Kota and Mahoney, *Manufacturing Prosperity*.

implementing a national manufacturing strategy and (2) providing sufficient, sustained, and coordinated federal resources focused on ensuring the long-term success of U.S. manufacturing.

Additional work by MForesight in 2019, *Reclaiming America's Leadership in Advanced Manufacturing*, confirmed the findings and recommendations in *Manufacturing Prosperity*, emphasizing the growing urgency to rebuild the nation's capacity for manufacturing innovation. Creating a National Manufacturing Foundation would clearly demonstrate U.S. commitment to strengthening national manufacturing capacity and to the steps needed to achieve this goal. The proposed NMF would be an independent agency akin to the National Science Foundation (NSF). It would invest in translational R&D (engineering and manufacturing R&D) to advance promising results from the R&D investments made by other science and technology (S&T) agencies from bench/pilot scale to large/commercial scale. It would also coordinate early adoption of emerging technologies for national security, help small and medium-sized manufacturers invest in technology and equipment upgrades, and help build the pipeline of domestic talent for all components of a robust, modern manufacturing. Overall, the NMF would build the intellectual, financial, and physical infrastructure needed for the United States to regain its capacity to manufacture its inventions at scale and to leverage its R&D for economic growth and national security.

## 2. State of U.S. manufacturing

American manufacturing—especially in advanced technology products—is under threat. In 2017, as Figure 1 illustrates, the United States had a positive trade balance in only two advanced industries: aerospace and (minimally) engines and turbines.<sup>7</sup> The United States does not maintain a positive trade balance even in industries such as medical devices and pharmaceuticals: industries where the U.S. federal government invests significant R&D and is the single largest customer. Furthermore, most domestic manufacturing industries use substantially more imported content than they did 20 years ago.<sup>8</sup>

Between 2006 and 2016, some of the largest reductions in U.S. manufacturing output were in advanced industries, including pharmaceuticals (down 3.1%), industrial machinery (2.9%), communications equipment (2.5%), and computers and peripherals (2.3%). Imports increased in all of these industries. Since 2013, imports from Asia have increased by 19% while U.S. manufacturing gross output has increased by just 1%.<sup>9</sup>

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<sup>7</sup> Data from the IBISWorld database, available at <https://www.ibisworld.com/united-states/market-research-reports/database-directory-publishing-industry/>.

<sup>8</sup> Sree Ramaswamy et al., *Making it in America: Revitalizing US manufacturing*, McKinsey & Company (November 2017).

<sup>9</sup> "United States Manufacturing Production", Trading Economics, 2019, <https://tradingeconomics.com/united-states/manufacturing-production>.

It is worth noting that Japan, Germany, and South Korea have maintained trade surpluses in advanced manufacturing, are well ahead of the United States in their use of industrial robots, and have a greater share of high-technology production in their manufacturing sectors. In 2017, the U.S had a \$859 billion trade deficit in goods, whereas Germany, Japan and South Korea (all high-wage countries with strict regulations and higher energy costs) had trade surpluses of \$279 billion, \$27 billion, and \$95 billion respectively.<sup>10</sup>

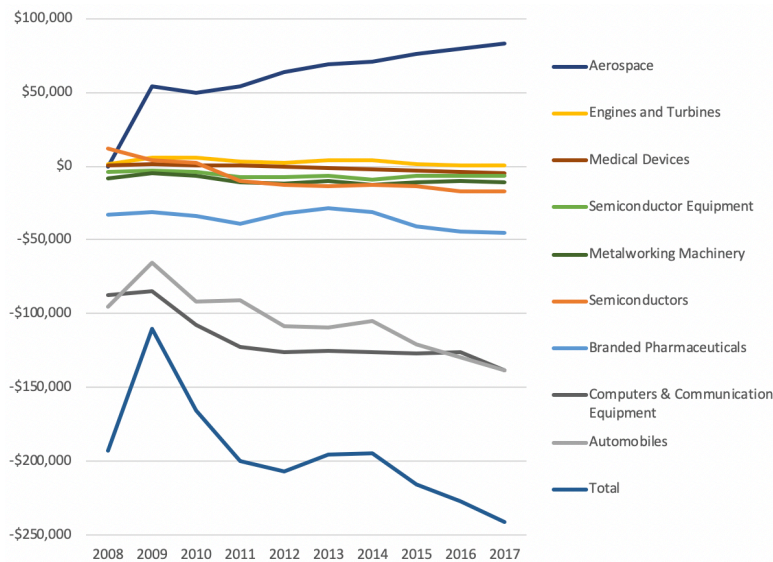


Figure 1: Net U.S. exports in advanced industries (\$ millions) (Source: IBISWorld)

<sup>10</sup> Data from the United Nations, <https://comtrade.un.org/data/>.

Since 2011, labor productivity in manufacturing has risen by only 0.7% total (Figure 2). Worse, total factor productivity in manufacturing actually fell by 5.8% between 2011 and 2015.<sup>11</sup>

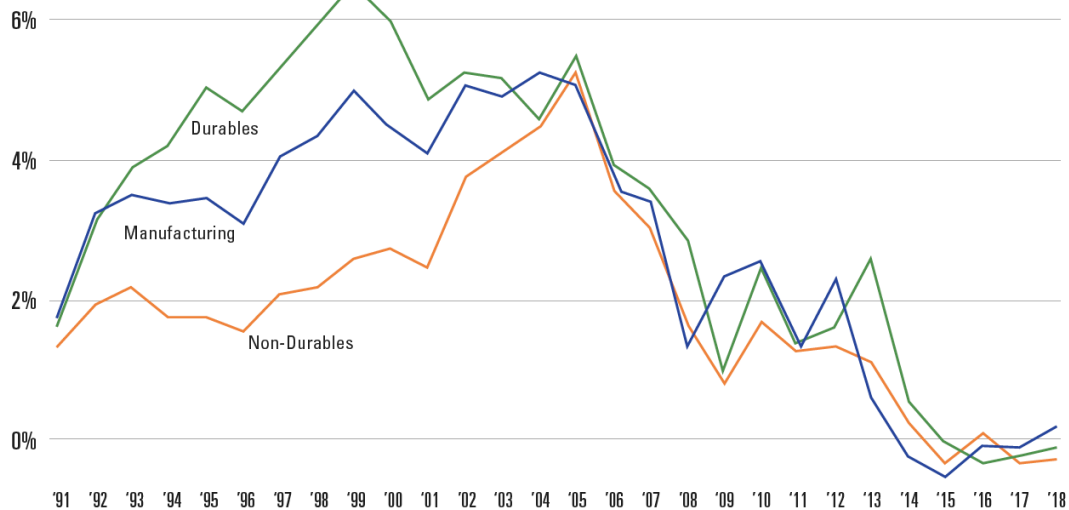


Figure 2: Change in U.S. Manufacturing Labor Productivity  
(Source: Bureau of Labor Statistics)

Much of these declines can be explained a nationwide drop in capital investment in machinery and equipment. Fixed assets fell from nearly 10% of U.S. GDP in the 1980s to less than 5% in 2018. The rate of investment in fixed assets by non-financial corporations averaged more than 5% between 1947 and 2000, but has been half that since then.<sup>12</sup> The result is not only greater dependence on imports in virtually every industry (and especially in defense-related industries), but also an older capital stock that makes domestic production much less competitive than it could be.

Since the 1980s, when U.S. manufacturing competitiveness was initially challenged by Japanese automotive and electronics companies, a few economists made the case that manufacturing matters to the innovative capacity and overall health of the nation.<sup>13</sup> Shifts in the composition of industrial production over time are to be expected in a healthy, dynamic economy. The United States was expected to shift from low-value, labor-intensive products to high-value, advanced technology products. But more than other advanced economies, the United States shifted away from advanced manufacturing,

<sup>11</sup> Peter Coy, "American Factories Have One Very Big Problem", *Bloomberg BusinessWeek*, May 9, 2018, <https://www.bloomberg.com/news/articles/2018-05-09/american-factories-have-one-very-big-problem>.

<sup>12</sup> Senator Marco Rubio, *American Investment in the 21<sup>st</sup> Century*, April 2019.

<sup>13</sup> See, e.g., Stephen Cohen and John Zysman, *Manufacturing Matters: The Myth of the Post-Industrial Economy*, New York: Basic Books (1987).

maintaining a consistent trade balance only in aerospace. Only recently have the negative consequences of this shift away from manufacturing been widely recognized: consequences that include precarious defense production, drug shortages, lost wages, declining communities, and missed opportunities. In too many cases, game-changing inventions emerging from U.S. labs have become blockbuster products manufactured somewhere else.

### **3. Factors contributing to U.S. manufacturing decline**

#### *3.1 Generating knowledge but not wealth*

Investments in basic research generate knowledge—scientific discoveries and engineering inventions. Innovation—technological and business—is the process of transforming a promising idea into a new product or a process at a large enough scale to meet societal needs. Investments in translational research generate engineering methods and manufacturing know-how to create national wealth and security. Unless the nation makes large and sustained investments in translational R&D, we will continue to offshore our innovation and manufacturing even if we double our investments in basic research or science.

The benefits derived from federal support for R&D are clear. Starting in the 2010s, nearly one-third of U.S. patented inventions relied on federal government funding.<sup>14</sup> For example, research supported by the Department of Defense (DOD) underlies touch screens, the Global Positioning System (GPS), and other technologies used in smart phones. Research supported by the Department of Energy (DOE) underlies lithium-ion batteries, hydraulic fracturing, solar panels, and light-emitting diodes (LEDs). Research supported by the National Institutes of Health (NIH) underlies biopharmaceuticals, advanced prosthetics, and gene therapy.<sup>15</sup> But these R&D investments made by the American taxpayers have generated significantly more national wealth in other countries than they have in the United States. Because many of the products resulting from these R&D breakthroughs are manufactured abroad. All of the economic activity associated with that production—factory construction, capital equipment investment, and wages across entire supply chains, as well as the associated multiplier effect—created wealth and spurred economic development in foreign countries, not here in the United States.

On the other hand, aerospace—an industry in which the U.S. continues to lead in advanced technology—is an instructive example of the power of strategic, long-term

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<sup>14</sup> L. Fleming, H. Greene, G. Li, M. Marx, and D. Yao, “Government-Funded Research Increasingly Fuels Innovation,” *Science*, vol. 364, issue 6446, June 21, 2019, pp. 1139-1141.

<sup>15</sup> Council on Foreign Relations, *Innovation and National Security: Keeping Our Edge*, Independent Task Force Report No. 77 (2019): 17.



government support. Aerospace is the last major industry that continues to maintain a strong trade surplus in the United States. Not surprisingly, the aerospace industry is also more dependent on government customers (mostly the DOD) and is the beneficiary of substantial government R&D investments in basic, translational, and applied research. The aerospace industry is the successful beneficiary of a de facto industrial policy to support an industry critical to national defense.

Continued federal support for R&D is essential to American invention. But if U.S. industry does not manufacture the resulting innovations, most of the economic benefits are lost to other countries. Imagine how many millions of jobs were created abroad from products largely invented in the United States over in the past two decades. No smart phones are made here, and China dominates global production of solar panels, lithium-ion batteries, and unmanned aerial vehicles (drones). There are other consequences to offshoring advanced manufacturing as well. For instance, growing dependence on pharmaceutical imports has led to recurring shortages of critical drugs such as Heparin.<sup>16</sup>

In addition, offshoring manufacturing greatly diminishes the nation's long-term capacity for innovation. Consider flat-panel displays such as those used in televisions. The technologies that enable most flat-panel displays were invented by U.S. companies and universities, emerging from basic research funded by the federal government. But few factories for LCD and LED large diameter flat panel displays were ever opened in the United States.<sup>17</sup> Without that production experience, U.S. companies have been unable to manufacture the next generation of flat and flexible displays, despite significant R&D investments by the U.S. military.<sup>18</sup>

The unfortunate reality is that the United States is at the forefront of enabling scientific understanding, but lags when it comes to producing the resulting global output. Our inability to scale emerging technologies is not due to high wages and strict regulations, but to the loss of our "industrial commons"—i.e., the investment, manufacturing knowledge, suppliers, and skills needed to advance products beyond the concept stage. Indeed, nations such as Germany, Japan and South Korea have robust advanced manufacturing sectors despite also having higher wages, stricter regulations, higher levels of automation and higher taxes than the United States. These countries are weathering China's rise far better than the United States. The difference is that

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<sup>16</sup> Anna Edney, "Mass Pig Deaths in China Cause Short Supply of U.S. Blood Thinner", Bloomberg, August 30, 2019, <https://www.bloomberg.com/news/articles/2019-08-30/mass-chinese-pig-deaths-cause-short-supply-of-u-s-blood-thinner>.

<sup>17</sup> There are currently two U.S.-based producers of OLED micro displays: Kopin in Westborough, Massachusetts and eMagin in Bellevue, Washington.

<sup>18</sup> The Flexible Electronics and Display Center established by the U.S. Army at Arizona State University in 2004 included multiple foreign partners such as Sharp, Auo, and LG.

multinational corporations based in these countries are not as focused on quarterly profits as U.S. multinationals. These foreign corporations therefore often have longer investment time horizons, with greater concern for the interests of multiple stakeholders rather than just shareholders. In fact, many of these foreign corporations have been investing in manufacturing facilities in the United States, attracted by the large U.S. market and unencumbered by the same emphasis on financial objectives as U.S. corporations. Some of these same corporations are also taking on significant technical and market risk by investing in nascent but promising technologies developed in the United States. In many cases, these corporations believe that they can leverage the engineering skill and the manufacturing capabilities in their home countries—capabilities that have been lost in the United States—to scale these technologies abroad and realize a profit.

It is important to note that for advanced technologies, a common argument in favor of offshoring manufacturing—lower labor costs—does not hold. Labor is a minor share of production costs for virtually all advanced technology products. Production processes for new advanced technologies are sophisticated and highly automated, and even previously labor-intensive processes such as semiconductor packaging and circuit-board assembly are now fully automated. In the short term, after having lost decades of manufacturing experience, American companies do indeed face challenges in finding the requisite skills and support infrastructure to reshore crucial parts of the value chain for advanced electronics manufacturing. But in the long term, there is no reason why the United States cannot compete with other countries in this arena. Indeed, we must start to compete now, or risk repeating the pattern for critical emerging technologies such as 5G communications, quantum information systems, advanced energy storage, and synthetic biology.

### 3.2 *Gaps in the national innovation cycle*

The United States still leads the world across a broad spectrum of discoveries, publications, and citations. Being the best in the world in science is important—but it's not sufficient to ensure success. As a nation, we're not investing sufficient public resources in turning these basic discoveries into new products and processes. Gaps in our nation's innovation cycle, from basic research to manufacturing, help explain why the United States is not capturing the full value of its investments in R&D. These gaps include:

- (1) **Brain drain.** The United States has long been dependent on foreign graduate students in science and engineering (S&E). Over one-third of S&E doctoral degrees (56% in engineering) from U.S. universities are awarded to foreign

students, a figure that is projected to grow to 50% in 2020 and beyond.<sup>19</sup> Historically, most of these students have stayed and worked in the United States for at least 10 years after graduation, but there is evidence that this pattern may be changing as opportunities increase in students' home countries. In particular, the Chinese government provides tuition and scholarships for many of its students to pursue advanced degrees in the United States with the expectation that those students return home after graduation. Many do, taking with them the cutting-edge knowledge, research experience, and results gained from their work.<sup>20</sup>

- (2) **Foreign investments in translational R&D.** The U.S. provides plenty of funding for basic science, but relatively little to support development and scale-up of commercial products. U.S. research institutions therefore partner with foreign entities to access capital and infrastructure needed to advance home-grown emerging technologies. Foreign investment often fills the gap. Many academic researchers establish research labs at foreign institutions to access funding needed to develop technologies created with initial support from U.S. federal agencies, sometimes in contradiction to U.S. laws and institutional policies.<sup>21</sup>
- (3) **Willingly giving away intellectual property (IP).** While IP theft by foreign competitors is an important concern, most instances of American IP use abroad are U.S. companies willingly licensing IP and U.S. startups voluntarily exporting their IP for production abroad, frequently by contract manufacturers in China. Foreign entities also access promising technologies from U.S. research institutions (as stated above), invest directly in high-risk, high-reward U.S. startups, and buy U.S. companies with specialized production processes (thereby gaining access to new technologies).
- (4) **Lack of investment, skills and know-how.** Scaling new technologies to volume production is costly and often requires engineering skills, production know-how, and a comprehensive supply base that is not readily available in the United States. Investors therefore frequently push startups to produce in China. A recent study of 150 hardware startups based on MIT technology found that none scaled production domestically mainly the "industrial commons" (see previous section) needed to do so was not available.<sup>22</sup>

For decades, our "strategy" has been to fund basic research and leave the follow-on activities to the magic hand of the free-market. As these gaps in the innovation cycle

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<sup>19</sup> Council on Foreign Relations, 51.

<sup>20</sup> U.S. Senate Permanent Subcommittee on Investigations, *Threats to the U.S. Research Enterprise: China's Talent Recruitment Plans*, (November 2019).

<sup>21</sup> Ibid.

<sup>22</sup> Richard M. Locke and Rachel L. Wellhausen (Eds.), *Production in the Innovation Economy*, Cambridge, MA: MIT Press, 2014.

emerged, it has become increasingly clear that a new national initiative is needed to convert research output into successful products and competitive industrial sectors in this country.

### 3.3 *Conflating science with engineering*

Science is not the same as engineering. Engineering involves not just analysis and discovery, but also synthesis and innovation aimed at turning abstract ideas into tangible products. Too frequently, engineering research at American institutions is hypothesis-driven rather than problem- or application-driven. This results in arcane, highly specialized investigations that lead to journal publications but little practical benefit.

Distinguishing between science and engineering may seem trivial but actually has profound effects on national R&D investments and outcomes. How a government allocates its resources among the two disciplines is both a reflection of and an influence on the prevailing national mindset.

The United States is already behind many foreign competitors in funding practical engineering research. Federal spending on manufacturing-related R&D is difficult to determine precisely due to insufficient information and inconsistent labeling. Estimates range from \$773 million<sup>23</sup> to \$3.7 billion.<sup>24</sup> A recent analysis by MForesight<sup>25</sup> estimates that in 2017, \$796 million of federal R&D spending could be reasonably attributed to manufacturing. Most of this money is federal spending through DOE’s Advanced Manufacturing Office, NSF’s Advanced Manufacturing Program, and DOD’s Manufacturing Technology (ManTech) programs. The remainder is federal funding (from DOD, DOE, and the Department of Commerce) and required non-federal cost share for the Manufacturing USA institutes. By comparison, Germany spends \$4.34 billion on “Industrial Production and Technology” research (six times U.S. spending). Japan and South Korea spend three and eight times as much, respectively (Figure 3).

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<sup>23</sup> Organization for Economic Co-operation and Development (OECD), “Industrial Production and technology,” Government Budget Appropriations or Outlays for R&D (GBAORD) for 2016, [https://stats.oecd.org/Index.aspx?DataSetCode=GBAORD\\_NABS2007](https://stats.oecd.org/Index.aspx?DataSetCode=GBAORD_NABS2007).

<sup>24</sup> In 2017, the Government Accountability Office surveyed 58 federal program offices across 11 agencies asking whether their activities helped foster (1) innovation, (2) global trade, (3) supported the workforce, or (4) offered financial or business assistance. The report found that 30 programs self-reported to be “fostering innovation through their support for basic and applied R&D” and that funding for these programs totaled about \$3.7 billion (table 3, pg.16). The agency breakdown suggests the survey included programs that support manufacturing R&D financially or business expertise, not just technology R&D. See U.S. Government Accountability Office, *U.S. Manufacturing: Federal Programs Reported Providing Support and Addressing Trends*, GAO-17-240 (March 2017).

<sup>25</sup> Mario Urdaneta, “Funding for Federal Manufacturing Technology R&D,” *Medium*, July 10, 2019, <https://medium.com/@MForesight/funding-for-federal-manufacturing-technology-r-d-58bfccaf3d1c>.

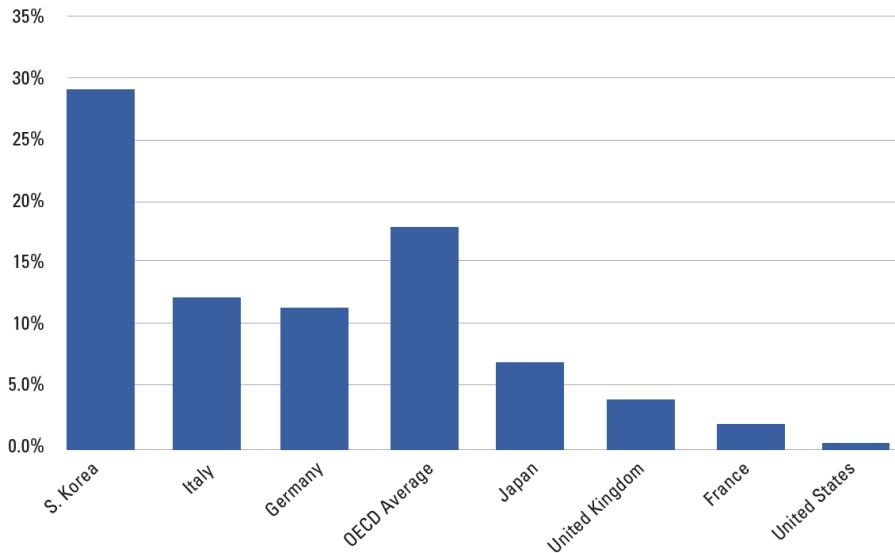


Figure 3: Share of total government R&D spending allocated for “Industrial Production and Technology” R&D, 2015 (Source: OECD)

Some would argue that manufacturing-related translational research is the role of private companies. However, American Original Equipment Manufacturers (OEMs), other than in the semiconductor and pharmaceutical industries, do not invest much in the translational R&D needed to mature the nascent technologies coming out of basic research and to mature manufacturing capabilities needed to scale up technologies of the future. Over three-quarters of business R&D is development focused on incremental product improvements.

It is also important to recognize that the large companies that conduct the vast majority of R&D in the American private sector have interests that extend beyond the United States. Many of America’s largest OEMs derived between half and two-thirds of their revenue from foreign sales in 2018—including Apple (58%), HP (65%), GE (62%), IBM (63%), and Caterpillar (58%).<sup>26</sup> Many of these companies employ more than half of their total workforce outside the U.S. and have more than half of their corporate assets outside the U.S. These companies have also been cutting costs by offshoring manufacturing and, increasingly, moving R&D abroad to their foreign affiliates. They cannot be counted on to restore American manufacturing.

### 3.4 Market failures

Restoring U.S. manufacturing leadership requires the public sector to step in to correct a market failure. Short-term profit incentives will drive the private sector to continue offshoring manufacturing (and R&D) as long as it is economically favorable—and it is.

<sup>26</sup> Howard Silverblatt, *S&P 500 2019: Global Sales, Indexology* (August 2019).

American firms are not concerned with the societal benefits that flow from domestic production in the form of jobs, national wealth, and national security. The manufacturing sector offers a wide range of job opportunities for blue-collar production workers and supervisors, as well as for white-collar researchers, design and manufacturing engineers, accountants, and business managers. In 2017, the average U.S. manufacturing worker earned \$84,832 in pay and benefits, 27% more than the average worker in non-farm industries,<sup>27</sup> and the multiplier effects from manufacturing exceed those of most other sectors. Manufacturing's economic footprint is nearly three times as large as its share of direct economic output (value added in 2018 was 11.3% of GDP<sup>28</sup>), and more than four times as large as its share of total U.S. employment. A significant portion of the domestic rise in income inequality, the long-term stagnation of personal income in the United States, and the redistribution of national wealth to coastal states is attributable to the loss of manufacturing employment, especially in the Midwest. Because the societal benefits of domestic manufacturing exceed the concentrated benefits of offshore manufacturing, the U.S. government has a critical role to play in realigning incentives.

### 3.5 *Past efforts*

Multiple defense programs and initiatives exist to address critical manufacturing issues in the United States. These include the Manufacturing Technology (ManTech) program, Title III, armories, the Manufacturing USA institutes, and the Defense Innovation Unit. Most of these are long-established programs that can at best address defense-specific production issues. They have not and will not arrest the long-term erosion of the U.S. innovation ecosystem and decline of broader U.S. manufacturing.

The Hollings Manufacturing Extension Partnership (MEP) at NIST is one of the few non-defense programs targeting manufacturers. Created in the late 1980s and analogous to the Agricultural Extension Service, MEP provides business and technical assistance to the nation's small and medium-sized manufacturers. Current funding is about \$140 million, but through much of its history, MEP has faced strong opposition from Republican administrations as an example of "industrial policy". Other advanced countries invest far more on programs to support SMMs and have had significantly better success than the U.S. in maintaining a strong manufacturing sector. Germany, for instance, invests 20 times as much as the United States on manufacturing extension services. Japan invests even more.<sup>29</sup>

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<sup>27</sup> "Facts About Manufacturing", National Association of Manufacturers (2019), <https://www.nam.org/facts-about-manufacturing/>.

<sup>28</sup> Data from the Bureau of Economic Analysis, <https://www.bea.gov/system/files/2019-10/gdpind219.xlsx>.

<sup>29</sup> Stephen Ezell, "International Benchmarking of Countries' Policies and Programs Supporting SME Manufacturers", Information Technology & Innovation Foundation, September 14, 2011, <https://itif.org/publications/2011/09/14/international-benchmarking-countries'-policies-and-programs-supporting-sme>.

Beginning in 2014, the most recent initiative launched to benefit domestic manufacturing, the Manufacturing USA institutes illustrate both the extent of the challenge and the need for a more comprehensive approach. Currently there are 14 institutes, addressing a range of specific production issues and technology segments. Each institute is a public-private partnership that focuses on promoting robust and sustainable manufacturing research and development in a specific, promising advanced manufacturing technology area. The program advances American manufacturing innovation by creating the infrastructure needed to allow U.S. industry and academia to work together to solve industry-relevant manufacturing problems in research and development, technology transition, workforce training, and education.<sup>30</sup>

The Manufacturing USA institutes are a worthwhile concept and deliver value for the niches that they address. But there are three main reasons why these institutes are insufficient to solve the broader manufacturing issues facing the United States. First, there are simply not enough institutes to have much impact across the national manufacturing sector. Federal funding for the institutes is less than \$200 million and the total number of member companies, fewer than 2000, is less than one percent of U.S. manufacturers.<sup>31</sup> Second, many of the institutes have yet to focus adequately on advancing technology and manufacturing readiness levels. Most of the institutes remain in start-up mode, focusing on building facilities and laboratories and increasing membership. Third, the scale of these institutes is such that only the largest corporations can provide sufficient matching funds and much of that has been in-kind support; larger cash contributions by members would increase research flexibility and strengthen members' commitment to achieving tangible outcomes.

The NMF would address shortcomings these existing programs by creating a comprehensive support system for the nation's manufacturing sector. A band-aid approach—spending more on the MEP program or creating a few new Manufacturing USA institutes, for example—will not restore the eroded industrial commons. A new agency with a national strategy and adequate and sustained investment could if we can act with some urgency. Other nations are not standing still.

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<sup>30</sup> See <https://www.manufacturingusa.com/about-us>.

<sup>31</sup> *Id.*

#### 4. Proposed action: establish a National Manufacturing Foundation

##### 4.1 Purpose

Based on research conducted in 2018 by MForesight,<sup>32</sup> the U.S. manufacturing community agrees that bold steps are needed to ensure that the challenges facing U.S. manufacturing are met quickly and aggressively. Market forces alone will not achieve the needed change. In fact, market forces have made manufacturing challenges worse over time. With sustained, strategic investments, the United States can regain fundamental manufacturing capabilities, rebuild its industrial commons, ensure a return on federal investments in R&D, capitalize on technology changes broadly affecting manufacturing, establish leadership in new industries, and restore the broad-based supplier networks that are essential to economic and national security. The objective is not to reshore lost industries but to rebuild our lost capabilities and capacities to establish and grow industries of the future.

An overarching recommendation in *Manufacturing Prosperity* is to establish a new federal agency, the National Manufacturing Foundation (NMF), to oversee and coordinate the federal government's manufacturing-related investments, initiatives, and policies. Currently, no single federal agency has the health of the nation's manufacturing as its primary mission. Although existing agencies have programs to support manufacturers (mostly targeting defense production) these programs are scattered, uncoordinated, and underfunded relative to the need. Most importantly, these small programs are always subordinate to the primary mission of their managing agency, be it defense, energy, labor, etc. Justifying programs to support manufacturing solely on the basis of national defense disregards the crucial high-wage employment, innovation, and wealth-building that only a strong, balanced commercial manufacturing sector can provide. A robust manufacturing sector is also essential to lessen our dependence on foreign countries for defense-critical technologies and security. And finally, the DOD alone can no longer build/rebuild the domestic industrial base on its own—defense procurement needs today are dwarfed by global commercial markets.

Although it might be politically easier to simply increase funding for existing manufacturing-support programs and to increase spending on engineering research, the results would be suboptimal. Such efforts would lack focus and likely lack the resources

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<sup>32</sup> MForesight: Alliance for Manufacturing Foresight is a federally funded advanced manufacturing research consortium. The results of its year-long study—including a series of round-table discussions across the nation on the challenges facing the United States in developing and implementing advanced product and process technologies—were published in *Manufacturing Prosperity: A Bold Strategy for National Wealth and Renewal*, available at <http://mforesight.org/download/7817/>. A related *Harvard Business Review* article, "How the U.S. Can Rebuild Its Capacity to Innovate," is available at <https://hbr.org/2018/10/how-the-u-s-can-rebuild-its-capacity-to-innovate>. A follow-on report with additional data, *Reclaiming America's Leadership in Advanced Manufacturing*, is available at <http://mforesight.org/download/8485/>.



and breadth needed to make a meaningful difference. A separate, independent agency is essential to ensuring a bright future for U.S. manufacturing. Similar steps have been taken before. Consider DOE, the NIH, and the National Aeronautics and Space Association (NASA). Each of these agencies was established pursuant to a federal determination that the sectors they manage (energy, healthcare, and aerospace, respectively) are critical to national well-being and so deserve large, focused government resources to ensure long-term American leadership. These agencies have been successful in achieving this goal. Similarly, if national leaders agree that the United States must also be a global leader in manufacturing, then creating a National Manufacturing Foundation is a necessary step.

The NMF would develop and implement a national strategy to achieve a world-leading manufacturing sector and would drive federal policy, programs, and sustained investments in accordance with this strategy. Certain existing programs such as the Hollings Manufacturing Extension Partnership (MEP) and Manufacturing USA would be transferred to the NMF. Other existing programs—for instance, defense-related programs—would retain their current organizational structure in order to avoid unnecessary disruption. The NMF would ensure close coordination among these programs. Most importantly, the NMF would provide strategic direction, fill programmatic gaps, maintain long-term focus, and track metrics to ensure federal efforts are making the expected difference in domestic manufacturing.

Specifically, the NMF would do the following:

- (1) **Engage with other federal S&T agencies** to set technology priorities, mature promising product and process technologies funded through other federal agencies, access relevant expertise, and coordinate funding to ensure that promising technologies receive full support from discovery and invention to commercial-scale domestic production.
- (2) **Invest in translational R&D** to help advance emerging technologies beyond the pilot stage. This would include awarding grants and contracts to U.S. universities and other research institutions to support translational engineering (not science) research and manufacturing process technologies common to multiple industrial applications. This would also include establishment of a series of Translational Research Centers (TRCs) affiliated with universities. TRCs would focus on advancing technology and manufacturing readiness of emerging technologies in order to enable successful hardware start-ups and to transform research results to new products and processes manufactured in the United States.

- (3) **Build connections between hardware start-ups and other federal agencies**, especially the DOD, to support translational research in defense-critical technologies. This would include leveraging federal purchasing power and the federal government's role as a customer to help American companies procure financing for plants and equipment to establish and ramp up production of new technologies.
- (4) **Facilitate public-private partnerships to create Manufacturing Investment Funds (MIFs)**. These MIFs would fill gaps in existing venture-capital markets, providing sufficient funding for hardware start-ups to scale production in the United States beyond pilot plants.
- (5) **Support small and medium-sized manufacturers (SMMs)** through technical assistance and financial support: including loans, grants, loan guarantees, and tax incentives. As the foundation of manufacturing value chains and the geographic distribution of diverse industrial clusters, it is essential that SMMs have the capacity to upgrade equipment, train staff, and fully participate in Industry 4.0.
- (6) **Grow engineering and technical talent at all levels** by significantly increasing federally funded graduate fellowships in engineering for U.S. citizens, partnering with state and local governments to increase the number of four-year engineering technology degree programs and to expand successful apprenticeship and skills-training programs.

This 6-point action plan is designed to address multiple shortcomings in the current U.S. manufacturing-innovation ecosystem. But to succeed, this plan must be complemented by policies ensuring that products based on the nation's R&D investments are manufactured domestically. In particular, we recommend a binding rule that if the intellectual property for a product or process is developed based on federally funded R&D, then that product or process must be manufactured substantially (e.g., a 75% minimum value-add) in the United States, without any exceptions or waivers.<sup>33</sup>

#### 4.2 *Implementation*

To accomplish these goals and fulfill its mission, we recommend funding the NMF with at least 5% of total federal R&D funding, or roughly \$7.5 billion per year. These funds should be appropriated to the NMF as part of an increase in total R&D funds, not as a carve out. This could be reasonably accomplished by starting with first-year funding of \$1 billion, then growing the NMF rapidly over 3–5 years until the 5% goal is met. To put these numbers in perspective, consider that the U.S. IP Commission has estimated the

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<sup>33</sup> Note that the Bayh-Dole Act already includes restrictions licensing IP to foreign entities, but waivers are routinely granted by funding agencies.

cost to the U.S. economy of IP theft, counterfeit goods, and pirated software by Chinese actors alone at nearly \$2 billion per day.<sup>34</sup> If we are serious about protecting our IP, bolstering our economy, and increasing defense preparedness, investing an additional 5% of federal R&D to create an NMF is necessary and urgent. Simply spending more on existing programs (e.g., doubling every existing S&T program for the next 10 years) will result in comparable costs but will not result in improved domestic industrial competitiveness—nor will it position the United States to establish the industries of the future. The NMF is the missing piece in our federal S&T programs.

An effective operational model is essential to meet stated goals. This not only includes sensible administrative structures and talented administrative personnel, but also strong mechanisms for engaging experienced engineers and business leaders. These experts would engage with researchers to identify promising technologies, design and conduct necessary translational research, and build the financial, legal, and technical mechanisms needed to transfer production to U.S.-based factories.

Metrics are also needed to assess progress on the NMF's overall objectives of strengthening domestic manufacturing and advancing commercialization of new technologies emerging from federally funded R&D. Metrics to consider include the number of technologies successfully reaching commercial production, number of jobs created in the manufacturing sector, number of new manufacturing facilities built in the United States., domestic availability of critical defense technologies, exports of advanced technologies, and returns on investment for both public and private stakeholders. Programs and initiatives that fail to demonstrate progress according to these metrics should be adjusted or terminated.

Aggressive action is needed to ensure that any new innovation supports domestic job creation and other economic-development goals in the United States. As stated above, the United States should encourage domestic production through minimal licensing fees and through government-procurement contracts. Legislation may be needed to ensure that any technology based on federally funded R&D must be scaled (e.g., a 75% minimum value add) in the United States. The federal government must provide clear, meaningful incentives to manufacture new hardware technologies in the United States—though it should not matter whether or not the entity that scales the technology is headquartered in America. In fact, many foreign manufacturers, such as BAE Systems (UK), Thyssenkrupp (Germany), Dassault Systems (France), and Ericsson (Sweden) have recently made large investments in the U.S., joining companies such as Toyota, Honda,

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<sup>34</sup> White House Office of Trade and Manufacturing Policy, *How China's Economic Aggression Threatens the Technology and Intellectual Property of the United States and the World* (June 2018): 5.

Siemens, and Hitachi that have invested in U.S. manufacturing for decades. Such investments must be further encouraged.

Government has played an indispensable role in American industrial development throughout history. Federal investments in basic and translational R&D, combined with early defense procurements, enabled creation of the aviation industry, semiconductors, computers, and the internet. Other federal investments led to horizontal drilling of shale gas/oil human-genome sequencing and CRISPR, and most of our advanced medical devices, pharmaceuticals, and treatments. The leading U.S.-manufactured exports today are aircraft and weapons—areas in which the federal government invests considerably in basic and translational R&D, and areas in which the government is the dominant customer.<sup>35</sup>

#### 4.3 Congressional action

The concept of establishing an NMF is receiving bipartisan support in the current U.S. Congress. Specific legislation is being developed to create the NMF and clearly define its role and mission. Senator Gary Peters (D-MI) has proposed<sup>36</sup> the creation of a National Institute of Manufacturing (essentially the same as an NMF), modeled on the National Institutes of Health, that would consolidate existing programs and invest in translational R&D to fill the gaps in the innovation cycle. Other ideas are being discussed in Congress that could strengthen federal support for U.S. manufacturing.<sup>37</sup>

## 5. Responses to possible criticisms

### 5.1 Creating and funding a new agency is difficult in a tight budget climate

Although a new agency would not fit within current budgetary constraints, the NMF should be considered a long-term investment in U.S. prosperity, not an additional cost burden. By defining the NMF budget as a percentage of the total R&D budget, funds would vary as Congress determines R&D appropriations. Perhaps a more important consideration is that the status quo is not sustainable. The nation's R&D enterprise cannot continue to focus on basic science research with limited capabilities to engineer and manufacture results domestically. Eventually, political support for continued R&D spending could wane, leaving both the overall economy and the defense industry worse off.

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<sup>35</sup> Between 2013 and 2017, the U.S. accounted for 34% of global arms exports. Source: Pieter D. Wezeman *et al.*, *Trends in International Arms Transfers, 2017*, SIPRI (March 2018).

<sup>36</sup> "Peters Announces Proposal to Establish a National Institute of Manufacturing, Make Manufacturing Policy a Major National Focus", June 8, 2019, <https://www.peters.senate.gov/newsroom/press-releases/peters-announces-proposal-to-establish-a-national-institute-of-manufacturing-make-manufacturing-policy-a-major-national-focus>.

<sup>37</sup> Based on conversations with multiple offices in both the Senate and House of Representatives.

### 5.2 *Government should not be picking winners and losers*

The argument that the government would be “picking winners and losers” by supporting domestic manufacturing is an argument that does not hold water. If anything, the opposite is true: without a robust domestic manufacturing sector, *other* countries have the power to pick *our* winners and losers by deciding which technologies developed here to mature and manufacture. The “picking winners and losers” argument also does not bear historical scrutiny. The United States has strongly favored specific industries in the past, through R&D spending, tax policy, and other policy levers. American leadership in industries such as aerospace, health care, oil and gas, and defense has depended on long-term government support. The fact that many advanced industries are now threatened by a weakening domestic production base and increasing dependence on imports indicates the need for a proactive role by government to restore American manufacturing. Furthermore, manufacturing ensures national security and provides greater employment opportunities for a larger number of people at higher wages than almost any other economic activity.<sup>38</sup> Support for manufacturing will help boost per-capita incomes, reduce income inequality, and restore the American Dream.

### 5.3 *There are so many manufacturing programs already. Why create a new one?*

The federal government has created a variety of manufacturing programs over the decades, and the DOD has long had internal programs to support defense manufacturers. Yet despite these programs, American manufacturing broadly has been declining three decades. None of the programs created to support manufacturing in the United States have had sufficient scale to make an impact beyond the edges. The 56 manufacturing programs across 11 federal agencies are not coordinated and are not motivated to do so. Unlike major foreign competitors such as Germany, Japan, and South Korea, the United States has never established a comprehensive set of programs and policies to nurture and support its manufacturing base and the innovation ecosystem. The United States cannot afford to continue a piecemeal approach to restoring its much-eroded industrial commons.

The NMF would also play an as-yet-unfilled role in ensuring that promising developments based on federally funded R&D are matured and ultimately produced at full scale in the United States. Too often, promising technologies emerging from basic research funding from one agency are sit idle instead of being commercialized. This may be because funding for continued development does not fit the mission of the original funding agency, other agencies that could fund further development are unaware of the new technologies, and the inventors do not know how to engage other agencies for

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<sup>38</sup> “Facts About Manufacturing”, National Association of Manufacturers (2019), <https://www.nam.org/facts-about-manufacturing/>.

continued funding. The NMF would be responsible for eliminating this situation through strategic coordination of S&T agencies.

## **6. Potential champions and advocates**

The recommendation to create an NMF is the result of MForesight’s discussions (totaling more than 1,200 hours) around the country with nearly 200 industry leaders, academics, investors, and state and local economic developers. These discussions revealed an urgent desire for a coordinated, long-term, and well-funded national manufacturing initiative, led by the NMF, to compete with the ambitious plans and actions of international competitors, such as China 2025.<sup>39</sup> Potential champions and advocates also include policymakers concerned about national security challenges, including the House and Senate Armed Services Committees; the DOD; the International Trade Administration; trade organizations including the National Defense Industries Association, the Association for Manufacturing Technology, and the National Association of Manufacturers; professional societies including the American Society of Mechanical Engineers, the Institute of Electrical and Electronics Engineers, and the Society of Manufacturing Engineers; and advocacy groups and think tanks including the Alliance for American Manufacturing, the Information Technology and Innovation Foundation, the Brookings Institute, the Heritage Foundation, and the Center for American Progress.

### *6.1 Opportunities for complementary action*

Creating the NMF would clearly indicate that the government is ready to support manufacturing. But the weaknesses in the national industrial base are too widespread for the federal government to solve on its own. Rather, the federal government must recognize the unique part that other sectors can and must play to truly position the United States as a global leader in manufacturing. Private industry can attract matching funds, expertise, and commitments to maintain and build factories in the United States. The private financial sector—investment bankers, venture capitalists, and retail banks—can provide the financial capital needed to scale production at home. Universities can commit to channeling research results and IP to domestic producers, not foreign competitors. Universities can also ramp up efforts to recruit domestic engineering students, and can strengthen investments in engineering training and degree programs. OEMs can restore apprenticeships and internship programs to train the needed skilled workforce. State and local governments can provide matching funds, ramp up educational programs for skilled trades, and offer incentives to encourage development of manufacturing clusters. State and local governments can also work with the NMF to

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<sup>39</sup> The Center for Strategic and International Studies has a short analysis of China 2025 at <https://www.csis.org/analysis/made-china-2025>. The full text can be found at <http://www.cittadellascienza.it/cina/wp-content/uploads/2017/02/loT-ONE-Made-in-China-2025.pdf>.

aggregate and accelerate place-based manufacturing initiatives for the benefit of the entire nation. The NMF provides a clear vehicle through which the federal government can work to ensure that all of these roles are filled.

## 7. Conclusion

The challenges facing American manufacturing have been building over decades as more and more industries have offshored production or been overwhelmed by imports. Dependence on imports matters relatively little for low-technology products.

But when that dependence encroaches on knowledge-intensive industries and defense production, the prospects for maintaining American defense superiority and a high-income, prosperous society come into question. Without a robust manufacturing sector, the United States cannot realize the full value—in terms of economic growth, job creation, national security, and capacity for continued innovation—of its investments in research and development.

Meanwhile, other countries are not standing still. China has set up a \$21 billion national investment fund to promote the transformation and upgrading of its manufacturing industry.<sup>40</sup> Japan, Germany, and South Korea all far outpace the United States when it comes to manufacturing investment and capabilities.

It is high time for the United States to restore its lost industrial commons and reposition itself as a global leader in product innovation, engineering, and commercialization. Establishing the National Manufacturing Foundation is a necessary and important step towards achieving this goal.

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<sup>40</sup> Samuel Shen and John Ruwitch, “China sets up \$21 bln fund to upgrade manufacturing”, Nasdaq, November 19, 2019, <https://www.nasdaq.com/articles/china-sets-up-%2421-bln-fund-to-upgrade-manufacturing-shanghai-sec-news-2019-11-19>.

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Tom Mahoney is Associate Director of MForesight, where he researches and writes about critical policy and technology issues affecting long-term U.S. manufacturing competitiveness, drawing on extensive experience in manufacturing management, policy, and entrepreneurship. At MForesight, Tom has written major reports on strengthening manufacturing supply chains, cybersecurity, Industry 4.0, and national policy initiatives to restore U.S. leadership in innovation. Prior to joining MForesight, Tom was CEO and co-founder of a technology startup perfecting a microwave plasma ignition and sensor system for internal combustion engines. Tom spent nearly 15 years as President of WMEP, Inc. providing business and technical consulting services to manufacturers. He also was the Senior Economist at the New Zealand Ministry of Research, Science and Technology, where he developed a national technology commercialization strategy. Tom began his work in manufacturing and innovation at the National Academy of Sciences, where he was Executive Director of the Manufacturing Studies Board addressing multiple research and policy issues regarding U.S. manufacturing competitiveness. Tom received his MA in International Economics and European Affairs at The Johns Hopkins University and his BA in economics from Davidson College.



### About the Day One Project

The Day One Project is dedicated to democratizing the policymaking process by working with new and expert voices across the science and technology community, helping to develop actionable policies that can improve the lives of all Americans, and readying them for Day One of a future presidential term. For more about the Day One Project, visit [dayoneproject.org](https://dayoneproject.org).