NATIONAL ACTION PLAN FOR UNITED STATES LEADERSHIP IN

Advanced Manufacturing

SPECIAL COMPETITIVE STUDIES PROJECT 06.2024

The Special Competitive Studies Project (SCSP) is a bipartisan, non-profit project with a clear mission: to make recommendations to strengthen America's long-term competitiveness as artificial intelligence (AI) and other emerging technologies are reshaping our national security, economy, and society.

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A Letter from the Chairman & the CEO

SCSP is developing a series of National Action Plans to ensure U.S. leadership in key technology areas. This action plan addresses advanced manufacturing, a technology battleground defined by the application of artificial intelligence (AI) and other emerging technologies to the industrial sector. The past 20 years have witnessed the proliferation of cheap sensors, rapid improvements in available computational power, and step-changes in AI performance. These trends enable the creation of intelligent factories that make the process of designing and building products more akin to software design.

Since the 1980s, U.S. firms have outsourced much of their production capacity to other countries in order to reduce costs and become more efficient. But this trend has had unintended consequences. For example, since skills and know-how tend to follow production, the nation is now experiencing workforce shortages across sectors. Outsourcing has also had a dampening effect on innovation. When production capacity is co-located with a nation's innovation ecosystem, tighter feedback loops are created between design and engineering, fostering more rapid innovation.

The national security implications of advanced manufacturing cannot be understated. Prudence requires that the United States rebuild its advanced manufacturing ecosystem — including both the know-how and capacity to build things that the country needs. We can do this by applying technology to the manufacturing process at scale. The passage of landmark legislation such as the CHIPS & Science Act and Inflation Reduction Act serves as a starting point, but additional efforts are needed to accelerate innovation in manufacturing processes and drive the deployment of advanced manufacturing technologies.

Drawing on expertise from academia, the private sector, and government, this action plan combines bold technology "moonshots" with organizational changes and policies that would position the United States for durable advantage. Many of the technologies needed to do this already exist, but a national-level effort, as well as collaboration with America's network of allies and partners, is needed to ensure these systems are deployed widely. We invite you to join us in this effort to ensure that the United States and other democracies are positioned and organized to win the techno-economic competition between now and 2030, the critical window for shaping the future.

Eric Schmidt
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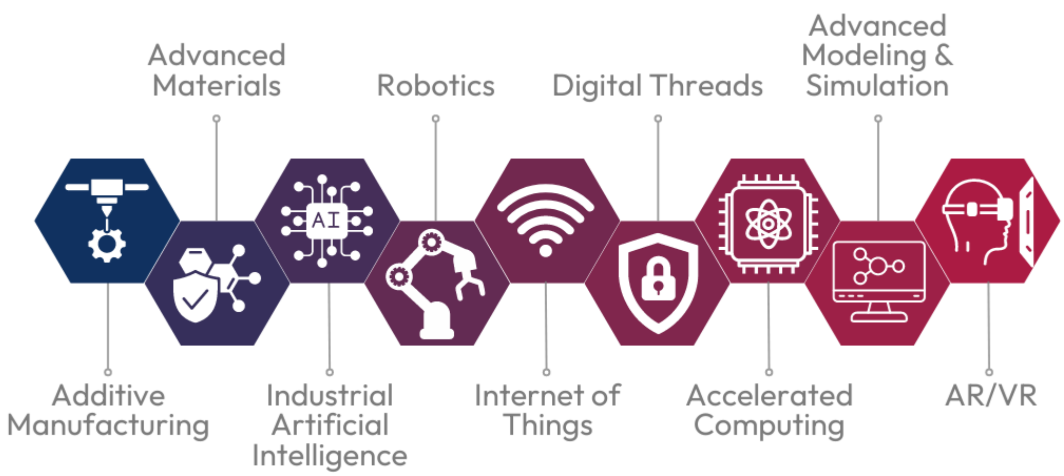
Introduction

The next industrial revolution is here. From AI and intelligent robotics to additive manufacturing and digital twins, a core set of technologies are converging to transform the nature of industrial production. Advanced manufacturing (ADVM) paradigms, which depend on the close integration of machining, networking, sensing, and computational capabilities, accelerate the design and production of physical goods in the material world.[1] The ability to adopt and improve these paradigms will increasingly determine the capacity of nations to compete in key technology battlegrounds.

Advanced Manufacturing as a Convergence Technology



U.S. industrial capacity has severely eroded in recent decades, posing significant challenges to economic competitiveness and security. In 1980, the United States manufactured over 40 percent of global high-technology goods, compared to just 18 percent today.[2] Meanwhile, the People's Republic of China (PRC) has cultivated unrivaled high-tech industrial production capacity and is responsible for nearly 30 percent of total global manufacturing output.[3] The PRC's "New Industrialization" policy identifies leadership in advanced manufacturing as critical to ensuring the success of its overall strategy of national rejuvenation.[4] Beijing intends to cement China's

[1] Report to the President on Ensuring American Leadership in Advanced Manufacturing, President's Council of Advisors on Science and Technology at ii (2011).
[2] Robert D. Atkinson, How to Win the Economic War With China, The International Economy at 44 (2023).
[3] Felix Richter, These Are the Top 10 Manufacturing Countries in the World, World Economic Forum (2020); Dan Wang, China's Hidden Tech Revolution: How Beijing Threatens U.S. Dominance, Foreign Affairs (2023).
[4] Minister: China in Full Swing to Promote New Industrialization, State Council Information Office (2023); Stan Deng Zhou, "New Industrialization, Why? What is it? Qiushi (2023).

position as the world's preeminent manufacturing superpower, entrenching asymmetries in industrial base capacity that call into question the ability of the United States to compete in advanced industries and prevail in protracted conflict.[5]

Accelerating the deployment of AI and other emerging technologies in manufacturing presents a unique window of opportunity for the United States to reconstitute its industrial base.[6] Industrial sectors are entering a transformative era, driven by the application of software and AI to the physical world. The United States boasts competitive advantages in AI and software-enabled innovation which, if married with large-scale investments in production capacity, can offset PRC advantages and position the nation for leadership across technology battlegrounds. Launching moonshot programs and making key organizational moves can accelerate the deployment of ADVM technologies at scale. This strategy will also require a range of supporting moves, including major investments in America's manufacturing workforce, judicious use of trade tools to insulate firms in democratic market economies from PRC overcapacity, and a step-change in cyberdefense for industrial systems.

Desired Endstate

- Reverse declining U.S. manufacturing productivity by accelerating the adoption of ADVM technologies, raising productivity growth to a level comparable with leading industrialized economies by 2030.

- Increase U.S. shares of global output in advanced industries by at least 20 percentage points within a decade.[7]

- Quadruple advanced manufacturing technology adoption among small and medium-sized manufacturers (SMMs) by 2030.[8]

[5] Barry Naughton, Re-Engineering the Innovation Chain: How a New Phase of Government Intervention is Transforming China's Industrial Economy, Mercator Institute for China Studies (2024); A Manufacturing Renaissance: Bolstering U.S. Production for National Security and Economic Prosperity, Ronald Reagan Institute (2021); Seth G. Jones, The U.S. Defense Industrial Base Is Not Prepared for a Possible Conflict with China, Center for Strategic and International Studies (2023).
[6] William B. Bonvillian, Advanced Manufacturing: A New Policy Challenge, Annals of Science and Technology Policy at 15 (2017).
[7] On metrics used to evaluate the competitiveness of advanced industries relative to the global average, see Robert D. Atkinson, The Hamilton Index: Assessing National Performance in the Competition for Advanced Industries, Information Technology and Innovation Foundation at 5 (2022).
[8] One 2022 study for the Department of Defense estimates that roughly 10 percent of SMMs are actively deploying ADVM technologies in their operations. Chris Peters, et al., Smart Manufacturing Adoption Study 2022, Auburn Interdisciplinary Center for Advanced Manufacturing Systems at 23 (2022).

- Establish strategic trade partnerships with democratic market economies to pool demand for advanced industrial goods, offsetting dependencies on foreign adversaries.
- Cyber-harden the U.S. industrial base to protect against systemic risk, including from AI-enabled attacks.
- Alleviate the manufacturing skills gap by launching ambitious, technology-forward workforce training programs.

Central Policy

Rapidly increase the capacity and productivity of the U.S. industrial base, blunting PRC advanced industrial dominance by accelerating the adoption of ADVM technologies at scale.

Background

Establishing U.S. leadership in advanced manufacturing has become a national priority.[9] The current administration, in particular, has worked with Congress to enact a range of industrial policies designed to enhance the nation's critical infrastructure and boost production capacity in strategic sectors. These public funds have catalyzed significant private investment across advanced industries from semiconductors to clean energy technology.[10] Yet we cannot declare victory too early: the United States is just beginning to make the large-scale investments needed to position the nation for enduring advantage and offset dependence on the PRC. Compared to other industrialized nations, America has underinvested in manufacturing innovation by an order of magnitude.[11] Ultimately, realizing the promise of a U.S. manufacturing renaissance will require major investments, coupled with the use of policy tools that shape market conditions to boost industrial capacity across strategic sectors.[12]

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[9] National Strategy for Advanced Manufacturing, Subcommittee on Advanced Manufacturing (2022).
[10] John Coykendall, et al., 2024 Manufacturing Industry Outlook, Deloitte (2023); William B. Bonvillian, Emerging Industrial Policy Approaches in the United States, Information Technology and Innovation Foundation (2021); Eric Van Nostrand, et al., Unpacking the Boom in U.S. Construction of Manufacturing Facilities, U.S. Department of Treasury (2023); FACT SHEET: Biden-Harris Administration Announces New National Security Memorandum on Critical Infrastructure, The White House (2024).
[11] Compared to other industrialized nations, America has underinvested in key manufacturing programs by an order of magnitude. See William B. Bonvillian & Peter L. Singer, Advanced Manufacturing: The New American Innovation Policies, MIT Press at 183 (2018).
[12] Elisabeth B. Reynolds, U.S. Industrial Transformation and the "How" of 21st Century Industrial Strategy, Journal of Industry, Competition and Trade (2024).

Technology Context

Advanced manufacturing is a convergence technology area, defined both by the application of digital technologies to the physical world and by innovation in the world of atoms. The application of digital technologies to manufacturing — culminating in the deployment of industrial AI systems — is accelerating the process of designing and producing goods, to the point that manufacturing is becoming increasingly akin to software development. Factories of the future will deploy industrial AI systems and high-fidelity simulation tools to gain an innovation advantage in the form of faster, more agile design and product cycles. But advanced manufacturing also encompasses fundamental process innovation, or alterations to the manufacturing process that improve *how* things are built. Process innovation can be highly disruptive, unlocking massive gains in cost and creating opportunities to achieve previously impossible scale.[13]

From Digitalization to Industrial AI. Advanced manufacturing is partially premised on using sensors and software tools to collect data on every step of the manufacturing process, then applying that information to produce goods in a more efficient way.[14] This process is often called *digitalization*. Application of software to manufacturing dates back to the mid-20th century, when engineers and researchers in the United States developed computer-numerically controlled (CNC) machine tools and computer-aided design (CAD) tools.[15] Both technologies leveraged software instructions to increase the efficiency and precision of manufacturing systems. Even today, deploying industrial AI requires that factories first be digitalized.[16]

With the introduction of industrial AI, manufacturing processes are no longer merely *automated*; they are becoming increasingly *intelligent*. In other words, manufacturing systems are shifting from operating according to pre-programmed instructions towards adjusting to conditions in real-time.[17] Applying AI to the manufacturing process can unlock a variety of economic and strategic benefits: productivity gains (and resulting cost savings), increased transparency of supply chains, and greater sustainability (due to reduced waste).[18]

In addition, the introduction of generative AI will impact manufacturing in several important ways. Intriguing applications include AI-powered copilots that serve as an "operating system" to help workers make sense of complicated factory data, as well as AI-supercharged design tools that create product designs from natural language descriptions. Most importantly, generative AI

[13] Michael A. Filler & Matthew J. Realff, Fundamental Manufacturing Process Innovation Changes the World, SSRN at 5-6 (2020).
[14] Stephen Ezell, Why Manufacturing Digitalization Matters and How Countries Are Supporting It, Information Technology and Innovation Foundation at 1 (2018).
[15] Goli Mohammadi, History of CNC Machining, Part 2: The Evolution from NC to CNC, Medium (2019).
[16] Options for a National Plan for Smart Manufacturing, National Academies at 17 (2024).
[17] Jensen Huang, GTC March 2024 Keynote with NVIDIA CEO Jensen Huang, NVIDIA GTC (2024); Options for a National Plan for Smart Manufacturing, National Academies at 18-21 (2024).
[18] Options for a National Plan for Smart Manufacturing, National Academies at 16-18 (2024).

unlocks cheap transitions between multimodal forms of data that could usher in a "ChatGPT moment for robotics."[19] Such a development might pave the way for widespread deployment of intelligent, general purpose "humanoid" robots by the end of the decade as companies seek pathways to navigate severe labor shortages.[20] A true robotics revolution would be disruptive, but there is reason to be cautiously optimistic. So-called collaborative robots have already enabled the adoption of human-machine teaming paradigms, freeing workers from dull, dirty, or repetitive tasks and opening better-paying careers in managing complex systems.[21]

Breakthroughs in industrial AI also blur into advances in hyperrealistic, physics-based simulation — another example of convergence between the digital and physical worlds in manufacturing. Thanks to the diffusion of compute via cloud access to powerful AI chips, it has become cheaper to test new designs, create prototypes, and simulate changes to manufacturing processes in a hyperrealistic computer simulation, or digital twin, than to test them in the physical world.[22] Building virtual models of manufacturing operations that remain anchored to reality is complex, expensive, and challenging, but companies that succeed could create outsized innovation and cost advantages over their competitors.

Process Innovation Makes Scaling Production Capacity Possible. Advanced manufacturing also encompasses innovation in the world of atoms. While digitalization and industrial AI can provide significant cost and quality gains, process innovation holds the potential to fundamentally change the cost curve for a manufacturing process, which can disrupt an entire industry. Process innovation often goes overlooked, but historically, changes in the manufacturing process have altered the economics of key industries, opening paths to scale. Key examples from recent history include the Watt process for power generation from steam, the Bessemer process for steel production, and the planar process for microelectronics.[23] Each of these innovations created new pathways for scale and changed the world in profound ways.

Ultimately, process innovation often means finding novel ways to manipulate raw materials — processes which are more efficient, more flexible, or meet more extreme requirements than traditional ways of shaping, cutting, and molding metals.[24] Additive manufacturing, the best-known of these methods, has become increasingly useful on the production line, enabling

[19] Melissa Heikkilä, Is Robotics About to Have Its Own ChatGPT Moment?, MIT Technology Review (2024); Cade Metz, How the AI That Drives ChatGPT Will Move Into the Physical World, New York Times (2024).
[20] Several U.S. firms have signaled intentions to achieve this goal. See, e.g., Alyssa Lukpat, AI Startup Making Humanoid Robots Raises $675 Million With Bezos, Nvidia in Funding Round, Wall Street Journal (2024).
[21] Jeremy Marvel, Collaborative Robotics Enabling Manufacturing Workforce and Productivity Growth, National Institute of Standards and Technology (2017).
[22] Jensen Huang, GTC March 2024 Keynote with NVIDIA CEO Jensen Huang, NVIDIA GTC (2024).
[23] Michael A. Filler & Matthew J. Realff, Fundamental Manufacturing Process Innovation Changes the World, SSRN at 5-6 (2020).
[24] Ryan Fletcher, et al., Manufacturing Process Innovation for Industrials, McKinsey Global Institute (2021).

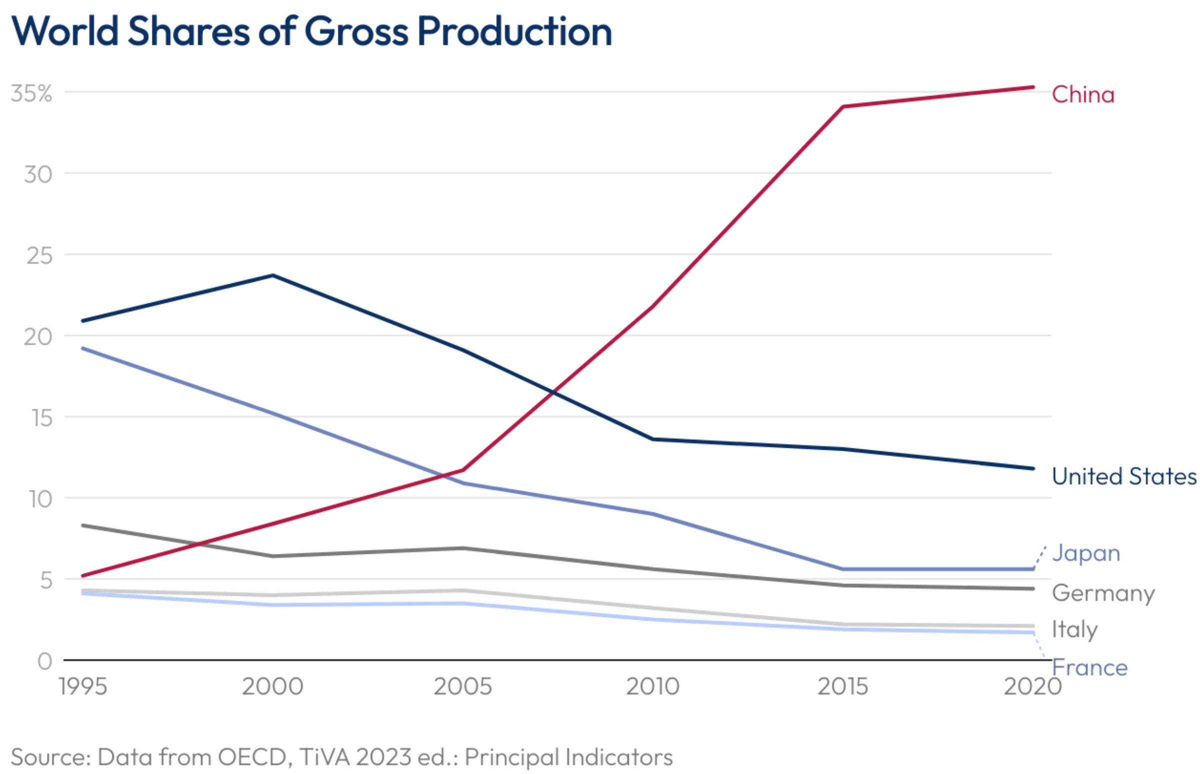
manufacturers to print high-strength metals and composites on-demand.[25] Additional process innovations have emerged in recent years that promise to further transform industry, including friction-stir welding, robotic sheet metal forming, and automated materials discovery and characterization.[26] Another intriguing example is biomanufacturing, which involves the growth of materials from biological feedstocks in fermentation tanks.[27]

Geopolitical Context

Recent Chinese policy guidance has identified manufacturing as "the main battlefield" in strategic competition.[28] Over roughly three decades, the PRC combined expansive industrial policies and "brute force" economic tactics to claim significant market share in a range of advanced industry verticals, from renewable energy to networking components, electrical equipment, and shipping.[29] From 1995 to 2020, China's global share of advanced industry output increased from 3 percent to 25 percent; much of this growth has come at the expense of the United States and its allies and partners.[30] Chinese Communist Party (CCP) leaders have consistently placed manufacturing at the core of China's long-term innovation strategy.[31] Beijing's *13th Five-Year Plan for Smart Manufacturing*, for example, describes developing China's intelligent manufacturing capabilities as the only way to "cultivate new driving forces for China's economic growth."[32] The Internet Plus Initiative, launched by the CCP in 2015, seeks for China to establish "an interconnected service-oriented industrial ecosystem by 2025" through the development of "intelligent factories."[33] Meanwhile, the CCP has placed increasing emphasis on leading in

[25] John A. Slotwinski, Additive Manufacturing: The Current State of the Art and Future Potential, Johns Hopkins Applied Physics Laboratory, Technical Digest (2021); Andrew P. Hunter, et al., Achieving an Additive Manufacturing Breakthrough, Center for Strategic and International Studies (2021).
[26] Isaac Maw, The What, Why and How of Roboforming, Engineering (2023); Nathan J. Szymanski, et al., An Autonomous Laboratory for the Accelerated Synthesis of Novel Materials, Nature (2023).
[27] See National Action Plan for U.S. Leadership in Biotechnology, Special Competitive Studies Project at 1-6 (2023).
[28] Implementation Opinions of Seven Ministries Including the Ministry of Industry and Information Technology on Promoting the Innovative Development of Future Industries, Center for Security and Emerging Technology (2024).
[29] China's share in advanced industries is 34 percent higher than the global average. See Robert D. Atkinson, The Hamilton Index: Assessing National Performance in the Competition for Advanced Industries, Information Technology and Innovation Foundation at 4-5 (2022); Liza Tobin, China's Brute Force Economics, Texas National Security Review (2023).
[30] Robert D. Atkinson & Ian Tufts, The Hamilton Index, 2023: China Is Running Away With Strategic Industries, Information Technology and Innovation Foundation at 9, 14 (2023); Richard Baldwin, China Is the World's Sole Manufacturing Superpower: A Line Sketch of the Rise, Centre for Economic Policy Research (2024); Trade in Value Added (TiVA) 2022 ed. Principal Indicators, Organization for Economic Co-operation and Development (2023).
[31] Made in China 2025, issued in 2015, elevated achieving leadership in "smart manufacturing" as key to sustaining China's "comprehensive national strength." See Wayne M. Morrison, The Made in China 2025 Initiative: Economic Implications for the United States, Congressional Research Service at 1 (2019); Rush Doshi, The United States, China, and the Contest for the Fourth Industrial Revolution, Brookings (2020).
[32] 13th Five-Year Plan for Smart Manufacturing, Ministry of Industry and Information Technology of China (2016).
[33] Stephen Ezell, Why Manufacturing Digitalization Matters and How Countries Are Supporting It, Information Technology and Innovation Foundation at 35 (2018); Emily Jin, Smart Manufacturing: A Linchpin in China's Industrial Policy, Lawfare (2023). See also John Lee, The Connection of Everything: China and the Internet of Things, Mercator Institute for China Studies (2021).

industrial robotics innovation and deployment, as indicated by the release of the *14th Five-Year Plan for the Robotics Industry* in 2021.[34]



Graphic Source.[35]

Rather than address structural imbalances in China's economy, the CCP has reemphasized advanced manufacturing industries — so-called "new forces of production" — as the critical engine of economic growth, aiming to promote "digital transformation" across the industrial sector while deepening its strategy to turn China into a "manufacturing powerhouse" (制造强国).[36] Over the next 12 months, PRC producers are set to flood foreign markets with subsidized advanced industry exports, undercutting firms in the United States and other democratic market economies.[37] Beyond commercial gains, creating overcapacity offers the regime in Beijing strategic benefits: asymmetric dependencies can be wielded as instruments of

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[34] Xiaogang Song, Understanding the New Five-Year Development Plan for the Robotics Industry in China, International Federation for Robotics (2022).
[35] Data from TiVA 2023 ed.: Principal Indicators, OECD.
[36] Outline of the People's Republic of China 14th Five-Year Plan for National Economic and Social Development and Long-Range Objectives for 2035, Center for Strategic and Emerging Technology at 19 (2021); 14th Five-Year Plan for Intelligent Manufacturing, MIIT (2021); Edward White & Cheng Long, Will Xi's Manufacturing Plan Be Enough to Rescue China's Economy?, Financial Times (2024).
[37] Keith Bradsher, More Semiconductors, Less Housing: China's New Economic Plan, New York Times (2023); Camille Boullenois, et al., Overcapacity at the Gate, Rhodium Group (2024).

statecraft, while excess production capacity can be pressed into service for wartime mobilization.[38]

Despite China's status as an advanced industrial powerhouse, various metrics suggest that advanced manufacturing remains a contested technology battleground. U.S. companies have a significant lead in generative AI, which is driving innovation across a range of advanced manufacturing activities. Like the United States, the PRC has experienced challenges in encouraging domestic manufacturing firms to adopt ADVM technologies: according to PRC state-affiliated sources, only 37 percent of manufacturers in China have reached a basic level of digitalization and industrial intelligence, while only 4 percent of Chinese manufacturers have attained leading-edge capabilities.[39] In terms of robotics deployment, however, China leads the United States and its allies and partners by a wide margin.[40] China has also established dominant positions in the production of key technologies for digitalized manufacturing, including legacy chips.[41]

Graphic Source.[42]

First Principles

The following first principles frame the national security and economic theory of the case for strengthening U.S. leadership in advanced manufacturing:

[38] Jason Douglas, The World Is in for Another China Shock, Wall Street Journal (2024); Victor D. Cha, Collective Resilience: Deterring China's Weaponization of Economic Interdependence, International Security at 95-102 (2023).
[39] Marc Levinson, U.S. Manufacturing in International Perspective, Congressional Research Service (2018); China Electronics Technology Standardization Institute (2022).
[40] World Robotics 2023 Report: Asia Ahead of Europe and the Americas, International Federation of Robotics (2023).
[41] Sujai Shivakumar, et al., The Strategic Importance of Legacy Chips, Center for Strategic and International Studies (2023).
[42] World Robotics 2023 Report: Asia ahead of Europe and the Americas, International Federation of Robotics (2023).

- **The Future Is Cyber-Physical.** Today's deep technologies lie at the convergence of bits and atoms.[43] The application of digital technologies in manufacturing speeds up hardware innovation but also risks introducing crippling cyber vulnerabilities.

- **Relink Innovation and Production Locally.** Co-location of innovation and production for advanced technologies allows for rapid feedback loops between design and engineering.[44] Severing this link by outsourcing production results in short-term cost advantages but undermines the ability of nations and firms to innovate in the long run.[45]

- **Regain Learning by Doing.** Manufacturing is subject to "learning effects": making high value-added technology products typically requires specialized process knowledge. In practice, this means that when firms or nations stop producing something, developing that capability again is an uphill battle.[46]

- **Protracted Conflict Is a Contest of Industrial Systems.** When great power wars become protracted, they tend to devolve into contests between manufacturing bases.[47] Thus, a national vision for accelerating the adoption of flexible, high-capacity manufacturing paradigms has significant implications for the military balance of power.

- **Advanced Manufacturing Is Clean Manufacturing.** Advanced manufacturing technologies, like additive manufacturing and industrial AI, increase efficiency while reducing emissions and waste. Deploying these technologies can help decarbonize the built environment.[48]

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[43] See, e.g., François Candelon, et al., How Deep Tech Can Drive Sustainability and Profitability in Manufacturing, Harvard Business Review (2023).
[44] Gary P. Pisano & Willy C. Shih, Does America Really Need Manufacturing?, Harvard Business Review (2012).
[45] Scott Stern, et al., The Determinants of National Innovative Capacity, National Bureau of Economic Research (2000).
[46] Gary P. Pisano & Willy C. Shih, Does America Really Need Manufacturing?, Harvard Business Review (2012); Joseph Stiglitz, Why Learning Matters in an Innovation Economy, The Guardian (2014).
[47] Andrew F. Krepinevich, Jr., The Big One: Preparing for a Long War With China, Foreign Affairs (2023).
[48] Brodie Boland, et al., Building Value by Decarbonizing the Built Environment, McKinsey Global Institute (2023); Robinson Meyer, Biden's Climate Law Is Ending 40 Years of Hands-Off Government, The Atlantic (2022).

Action Plan Overview

1. Launch: Moonshots to Strengthen the Industrial System-of-Systems

1.1 Build 1,000 Factories of the Future
1.2 Create a Manufacturing ARPANet

2. Organize: Close Gaps in the Manufacturing Innovation Ecosystem

2.1 Scale and Reimagine the Manufacturing USA Program
2.2 Create a Data Foundry Network for Industrial AI
2.3 Establish a White House Office of Manufacturing

3. Innovate: Establish U.S. Leadership in Manufacturing Technology Innovation

3.1 Create a Bell Labs for Manufacturing
3.2 Increase Advanced Manufacturing-Related R&D
3.3 Scale the Materials Genome Initiative

4. Promote: Accelerate Technology Adoption and Enable Scale-Up Capacity

4.1 Retool the Manufacturing Extension Partnership (MEP) as a System Integrator
4.2 Close Capital Access Gaps for SMMs
4.3 Create a National Network for Additive Manufacturing
4.4 Deploy Large-Scale Financing Mechanisms to Bolster Domestic Production

5. Pushback: Defend U.S. Markets from PRC Overcapacity

5.1 Build Trade Alliances with Allies and Partners
5.2 Leverage Section 301 to Secure Access to Critical Technology Inputs
5.3 Utilize Section 232 to Build Resilient Supply Chains with Allies and Partners

6. Defend: Cyber-Harden the Allied Industrial Base

6.1 Defend the Industrial Base with Automated Cyberdefenses
6.2 Develop Secure "Digital Threads" for Cyber-Physical Systems
6.3 Secure Supply Chains for Digital Infrastructure

7. Cultivate: Tackle Talent Shortages and Skills Gaps

7.1 Train One Million Manufacturing Workers with Cyber Skills by 2030
7.2 Build a National Advanced Manufacturing Talent Marketplace
7.3 Establish an American Manufacturing Corps
7.4 Reconceptualize the "Manufacturing" Workforce

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Launch: Moonshots to Strengthen the Industrial System-of-Systems

Moonshots are audacious goals that can move the entire U.S. innovation ecosystem toward a position of competitive advantage. By aiming to achieve a step-change or paradigm shift, such programs drive the rest of the innovation ecosystem along with them. Properly designed moonshots promote accountability by assigning a National Mission Manager to own the program full-time. Ultimately, moonshots aim to create a tangible platform, or capability, that solves an especially hard problem and creates second-order benefits for the economy.[49]

1.1 Build 1,000 Factories of the Future

At the upper echelon of the U.S. industrial base sit a small number of state-of-the-art facilities operated either by large original equipment manufacturers (OEMs) or by a small number of startups. These Factories on the Future[50] are characterized by being software-defined and having a high degree of autonomy, modularity, and flexibility.[51] The technological sophistication of these factories have enabled production-as-a-service business models, increasing the capacity of firms to produce a range of differentiated, high-value added products at scale in

[49] For more on the Positioning School logic that drives this thesis, see Harnessing the New Geometry of Innovation, Special Competitive Studies Project at 30 (2022).
[50] See also, Vision for Competitiveness: Mid-Decade Opportunities for Strategic Victory, Special Competitive Studies Project at 42 (2024).
[51] Aria Alamalhodaei, Hadrian Automation's CEO Wants to Defy History and Revitalize American Industry, TechCrunch (2024). The World Economic Forum's Global Lighthouse Network, for example, identifies 153 industrial facilities across the globe that uniquely integrate ADVM technologies, from AI and robotics to cloud computing and big data. Global Lighthouse Network: Transforming Advanced Manufacturing, World Economic Forum (2024).

response to shifting demand conditions.[52] With investment in manufacturing facilities booming, the United States should incentivize the construction of such facilities.[53]

Objective: Increase the capacity, productivity, and agility of the U.S. industrial base by providing incentives for leading-edge, digitalized production facilities.

Method: An Investment Tax Credit program, similar to tax incentives offered via the CHIPS Act and overseen by the National Institute of Standards and Technology (NIST), should support construction, retrofitting, and capital equipment purchases for qualifying facilities, up to an appropriate threshold. A third party should be selected to develop a scoring system that evaluates qualifying greenfield and brownfield facilities and allows for peer-to-peer learning. Additional scale-up financing may also be needed (see LOE III).

1.2 Create a Manufacturing ARPANet

Creating an AI-enabled digital twin of the entire U.S. industrial base today would allow for dynamic tracking and resource allocation during a conflict scenario. In the leadup to World War II, the United States mobilized to create a network of government entities to allocate resources and expand production capacity for war materiel.[54] AI-enabled supply chain mapping software already enables firms and governments to create a digital model of their supplier network, allowing for enhanced transparency and the ability to better predict the impact of disruptions and thus avoid supply shortages. Beijing has a head start in building such a system, prioritizing a national digital strategy[55] that includes "industrial internet" platforms that network producers and facilitate data sharing across China's manufacturing ecosystem.[56]

Objective: Network defense-relevant supply chains (including the aerospace, defense, microelectronics, and energy sectors), leveraging AI to dynamically model production capacity and potentially allocate and optimize resources in real-time during a conflict.

Method: An AI-enabled "National Industrial Digital Twin" should be developed to identify, network, and mobilize key suppliers and producers in the event of a protracted conflict. The White

[52] Daniel Küpper, et al., Boosting Resilience with Production as a Service, Boston Consulting Group (2022); Brian Heater, Machina Labs Emerges From Stealth with $16M Raised For On-Demand Manufacturing Robotics, TechCrunch (2023); Ilene Wolff, Go for Zero-Downtime Performance by 'Testing the Machine's Blood', Society of Manufacturing Engineers (2021).
[53] Eric Van Nostrand, et al., Unpacking the Boom in U.S. Construction of Manufacturing Facilities, U.S. Department of Treasury (2023).
[54] David Vergun, During WWII, Industries Transitioned from Peacetime to Wartime Production, U.S Department of Defense (2020).
[55] David Dorman, China's Plan for Digital Dominance, War on the Rocks (2022).
[56] Yi Wu, Industrial Internet in China: How Policies Enable Latest Stage of Industry 4.0, China Briefing (2023); Chunxiao Jiang, et al., Rethinking Development and Major Research Plans of Industrial Internet in China, Fundamental Research (2024).

House should deputize a National Mission Manager to build such a platform, which could support the Department of Defense (DoD) in a conflict scenario.[57] These efforts could also build on technical programs spearheaded by the Advanced Research Projects Agency-Energy (ARPA-E) and the U.S. Department of Transportation (USDOT), which are working to develop simulated models of key supply and demand and freight and logistics networks.[58]

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Organize: Close Gaps in the Manufacturing Innovation Ecosystem

2.1 Scale and Reimagine the Manufacturing USA Program
2.2 Create a Data Foundry Network for Industrial AI
2.3 Establish a White House Office of Manufacturing

When the United States organized its innovation system after World War II, the nation accounted for over half of the world's total manufacturing capacity and three quarters of its invested capital.[59] Ensuring that novel breakthroughs were backed by sufficient production capacity was simply not an item that policymakers needed to address.[60] Over the ensuing decades, however, outsourcing production capacity gradually severed the link between innovation and manufacturing, eroding U.S. technological competitiveness in key industries.[61] Recent years have seen growing efforts to put manufacturing at the center of the U.S. innovation system, including in the form of new institutional infrastructure, but key programs remain significantly under-resourced.[62]

[57] Work on this platform could be led by a federally funded research and development center (FFRDC).
[58] See Xueping Li, et al., A Cognitive Freight Transportation Digital Twin for Resiliency and Emission Control through Optimizing Intermodal Logistics (RECOIL), Advanced Research Projects Agency - Energy (2024); Freight Logistics Optimization Works, Bureau of Transportation Statistics (last accessed 2024).
[59] Melvyn Leffler, The Emergence of an American Grand Strategy, 1945–1952, in The Cambridge History of the Cold War, Cambridge University Press (2010).
[60] William B. Bonvillian & Peter L. Singer, Advanced Manufacturing: The New American Innovation Policies, The MIT Press at 34 (2018).
[61] Edlyn V. Levine, America Innovates, but China Reaps the Benefits, Newsweek (2023); Sridhar Kota & Tom Mahoney, Innovation Should Be Made in the U.S.A., Wall Street Journal (2019).
[62] See David Adler & William B. Bonvillian, America's Advanced Manufacturing Problem—and How to Fix It, American Affairs (2023).

2.1 Scale and Reimagine the Manufacturing USA Program

The U.S. Government's support of the manufacturing innovation ecosystem is largely organized around the Manufacturing USA program, a network of 17 institutes focused on accelerating manufacturing innovation.[63] Each Manufacturing USA Institute focuses on the development of a specific ADVM technology — such as robotics, advanced fabrics, biomanufacturing, photonics, and microelectronics — and is established as a public-private partnership jointly funded by a federal agency.[64] In addition to conducting applied R&D, the institutes offer additional benefits such as shared equipment for technology prototyping or testing and educational and workforce development programs.[65] By and large, Manufacturing USA has proven an effective model, yet two major challenges still remain, both related to insufficient resourcing. First, institutes lack a clear pathway to scale innovative pilot programs. And second, the unrealistic expectation that institutes will reach financial self-sufficiency incentivizes a siloed focus on discrete R&D projects, at the expense of public goods like education and workforce training.

Objective: Sufficiently scale the Manufacturing USA program to accelerate innovation and commercialization of ADVM technologies.

Method: Key actions should include:

- **Resource the Manufacturing USA program as a national strategic asset**. In FY 2021, federal base funding for the network of 17 institutes was just $127 million.[66] Base funding should be increased by an additional $500 million per year. In nominal terms, present levels pale in comparison to funding for similar programs in both allied and competitor nations, even before accounting for the larger size of the U.S. manufacturing sector relative to most of its peers.[67]

- **Eliminate five-year term limits for the Manufacturing USA institutes**. Instead, funding terms should be extended, and funding levels raised, through transparent evaluation

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[63] Institutes, Manufacturing USA (last accessed 2024).
[64] See Institutes, Manufacturing USA (last accessed 2024).
[65] William B. Bonvillian, Encompassing the Innovation Panoply, Issues in Science and Technology (2022).
[66] Report to Congress FY 2021, Manufacturing USA at 10 (2022).
[67] Ian Clay, Recent U.S. Manufacturing Employment Growth Hides the Sector's Abysmal Productivity Performance, Information Technology and Innovation Foundation (2023). By contrast, Germany's Fraunhofer-Gesellschaft network, comprising 76 institutes that conduct applied research — largely in manufacturing-related fields — enjoys an annual budget of $3.4 billion. See Paul Smith-Goodson, IBM And Fraunhofer Announce German Quantum Computing Partnership, Forbes (2021). China has followed the United States' example and has created 21 institutes with plans to create a total of 40 by 2025. See John F. Sargent Jr., Manufacturing USA: Advanced Manufacturing Institutes and Network, Congressional Research Service at 20 (2022).

processes that measure the performance of the institutes across a range of standardized metrics.[68]

- **Network the Manufacturing USA institutes to collaboratively develop integrated packages of technologies**. Relevant entities, including the Manufacturing USA Council, the Institute Directors Council, and the interagency Advanced Manufacturing National Program Office (AMNPO), should work to ensure technology packages under development at various institutes can be easily adopted by companies, while also working to ensure that R&D agencies are funding early-stage research that can be picked up by the institutes at later stages of development.[69] Networking the institutes more closely will also require targeted updates to Manufacturing USA's governance model. For example, driving adoption of industrial AI will require firms and institutes to value industrial datasets as part of the program's cost-share.

2.2 Create a Data Foundry Network for Industrial AI

Industrial AI systems must be trained on huge amounts of cleaned, high-quality data, well beyond what a single firm can provide. One key challenge, however, is that manufacturing industries are characterized by a reluctance to share data, especially in the absence of a trusted third party. Complicating matters, firms rely on an array of equipment and software platforms which are often incompatible. These factors present barriers to interoperability and have caused AI adoption in manufacturing to lag behind other industries.[70] Ultimately, accelerating adoption of AI in manufacturing will require three elements: making large datasets available to both small and large manufacturers; crafting open-source protocols for data sharing and integration; and training skilled system integrators and end-users who can deploy and use these systems.[71]

Objective: Establish a distributed, open-source network to collate and distribute datasets, promote standards for industrial AI.

Method: Establish a national network for AI in manufacturing spearheaded by the recently announced AI for Resilient Manufacturing Institute.[72] A national network would work with other

[68] William B. Bonvillian, Ensuring Manufacturing USA Reaches Its Potential, Day One Project at 6 (2021). On the concept of "translational research," see Sridhar Kota & Tom Mahoney, Reclaiming America's Leadership in Advanced Manufacturing, MForesight: Alliance for Manufacturing Foresight at 31-32 (2019). For additional discussion of possible evaluation criteria, see John F. Sargent Jr., Manufacturing USA: Advanced Manufacturing Institutes and Network, Congressional Research Service at 10-11 (2022).
[69] William B. Bonvillian, Ensuring Manufacturing USA Reaches Its Potential, Day One Project at 9 (2021); see also Charter of the Institute Directors Council Manufacturing USA, National Institute of Standards and Technology at 1-2 (2016).
[70] Towards Resilient Manufacturing Ecosystems Through Artificial Intelligence, National Institute of Standards and Technology at 3 (2022).
[71] See Natan Linder, Open Technology Ecosystems Are The Future Of Manufacturing, Forbes (2023).
[72] NOI: AI for Resilient Manufacturing Institute, National Institute for Standards and Technology (2024).

public-private partnerships to securely aggregate manufacturing datasets, broken out by industry vertical. In addition, it could share best practices for deploying industrial AI systems, recommend system integrators, and assist with workforce development efforts.[73]

2.3 Establish a White House Office of Manufacturing

The urgency placed on manufacturing and industrial strategy in recent years demands an authoritative institutional response. Successful implementation of the National Strategy for Advanced Manufacturing will require intensive planning and coordination across a complex patchwork of organizational entities at the federal, state, and local level.[74] An Executive Branch mechanism is needed to drive strategic alignment between programs and bring White House-level urgency to manufacturing policy.[75]

Objective: Create a White House-level office to set national goals for advanced manufacturing and encourage coordination between interagency programs.

Method: The United States should establish a Manufacturing Office within the Executive Office of the President, backed by a dedicated staff and institutional resources.[76] Establishing such an office would help drive strategic alignment among the various manufacturing-related programs, initiatives, and institutions that exist across the nation, including those focused on streamlining national approaches to ADVM workforce development.[77]

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[73] Rich Press, NIST to Launch Competition for AI-Focused Manufacturing USA Institute, National Institute for Standards and Technology (2024).

[74] National Strategy for Advanced Manufacturing, The White House at C-20-21 (2022).

[75] Concepts from this recommendation are found in a proposed House bill seeking to establish an Office of Manufacturing and Industrial Innovation Policy (OMIIP) within the Executive Branch — led by the Chief Manufacturing Officer — which would serve the primary function of advising the Executive Office of the President on policy issues relating to ADVM and coordinating federal departments and agencies. H.R. 1710, Office of Manufacturing and Industrial Innovation Policy Act of 2023.

[76] William B. Bonvillian, Ensuring Manufacturing USA Reaches Its Potential, Day One Project at 9 (2021). Currently, a Special Assistant to the President (SAP) for Manufacturing in the NEC leads interagency coordination on manufacturing issues. One option to achieve this recommendation is for the President to elevate the SAP position to a Deputy Assistant to the President (DAP) and provide a staff with the requisite expertise and experience to assist the DAP.

[77] For an overview of these various programs, institutions, and initiatives that would benefit from collaboration, see FACT SHEET: Biden-Harris Administration Highlights New Commitments Toward Equitable Workforce Development in Advanced Manufacturing, The White House (2024).

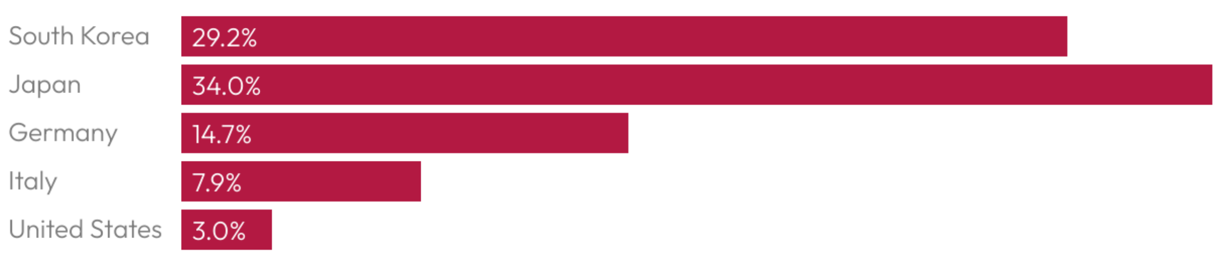
ACTION PLAN RECOMMENDATION 3 / 7

Innovate: Establish U.S. Leadership in Manufacturing Technology Innovation

3.1 Create a Bell Labs for Manufacturing
3.2 Increase Advanced Manufacturing-Related R&D
3.3 Scale the Materials Genome Initiative

U.S. spending on manufacturing-related R&D as a share of GDP remains far below the amount invested by other advanced economies.[78] U.S. R&D agencies, such as the National Science Foundation and DARPA, have comparatively small portfolios for manufacturing process technologies.[79] To lead in advanced manufacturing, the United States must build on existing efforts to establish leadership positions in manufacturing process innovation. Examples of areas that deserve additional attention include large-area additive manufacturing, AI-enabled modeling and design tools, in-space manufacturing, biomanufacturing and biomining, and atomically-precise manufacturing, among others.[80]

Share of Total R&D Spent on Manufacturing-Related R&D



Graphic Source.[81]

[78] Sridhar Kota & Tom Mahoney, Reclaiming America's Leadership in Advanced Manufacturing, MForesight: Alliance for Manufacturing Foresight at 19-20 (2019).
[79] David Adler & William B. Bonvillian, America's Advanced Manufacturing Problem—and How to Fix It, American Affairs (2023).
[80] National Strategy for Advanced Manufacturing, The White House at 9-10 (2022); Beth Reece, Leaders Outline Agency's Role in DOD Additive Manufacturing Capabilities, U.S. Department of Defense (2023); Advanced Manufacturing Office Research & Development Projects, U.S. Department of Energy (2019); In-Space Servicing, Assembly, and Manufacturing National Strategy, The White House (2022); Biotechnologies to Ensure a Robust Supply of Critical Materials for Clean Energy, ARPA-E (2020).
[81] Data from Government Budget Allocations for R&D, OECD (2022).

3.1 Create a Bell Labs for Manufacturing

Bell Laboratories, founded in 1925, is one of history's greatest models of industrial research and innovation. Its contributions spanned disciplines, including telecommunications, computation, and materials science. Bell Labs is remembered for fostering an environment that emphasized risk-taking and end-to-end R&D, leading to groundbreaking innovations in platform technologies like the transistor, the laser, the photovoltaic cell, and the UNIX operating system. The success of Bell Labs was, in part, a result of its incentive structure: scientists and engineers were free to tinker and encouraged to work across disciplines over long time horizons.[82] Since manufacturing R&D often falls through the cracks between the portfolios of government R&D agencies, academic research, and industry, breakthroughs in process innovation may require similar parameters.

Objective: Position the United States as a global leader in manufacturing process innovation. Cross-disciplinary innovation in process technology has long been overlooked by federal R&D funders, which tend to be project-based and siloed within engineering disciplines.

Method: Create or scale an independent, non-profit research organization focused on seeding process innovation that could unlock 1,000x gains in strategic sectors, like microelectronics and energy systems and storage. Such an organization could adopt a "focused research organization" model and would receive funding or in-kind contributions from industry, academia, and government funders.[83]

3.2 Increase Advanced Manufacturing-Related R&D

Even when the spending category is modified to include all ADVM-related R&D, at an estimated $2.9 billion as of 2019, the United States comes in last among OECD nations on manufacturing-related R&D. By comparison, South Korea allocates nearly 30 percent of its total R&D budget toward manufacturing-related R&D — more than 10 times as much as the United States on a relative basis — with Germany and Japan following closely behind.[84] Meanwhile, although firms in manufacturing industries have historically conducted a significant share of total U.S. corporate R&D, the share of R&D spending by manufacturers has fallen in the United States since 1980.[85]

Objective: Increase U.S. manufacturing-related R&D to close gaps with other industrialized nations.

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[82] Iulia Georgescu, Bringing Back the Golden Days of Bell Labs, Nature Reviews Physics (2022).
[83] Adam Marblestone, et al., Unblock Research Bottlenecks with Non-Profit Start-Ups, Nature (2022).
[84] Sridhar Kota & Tom Mahoney, Reclaiming America's Leadership in Advanced Manufacturing, MForesight: Alliance for Manufacturing Foresight at 19-20 (2019).
[85] In 1990, manufacturers spent over 83 percent of total private sector R&D dollars in the U.S. Their spending fell to below 60 percent in 2002, then recovered to 66 percent in 2015. Sridhar Kota & Tom Mahoney, Manufacturing Prosperity: A Bold Strategy for National Wealth and Security, MForesight: Alliance for Manufacturing Foresight at 19-21 (2018).

Method: The United States should work towards devoting a larger portion of its total federal R&D budget to manufacturing-related R&D, in order to bring it closer in line with comparable industrialized nations such as Japan and Germany. In addition, the United States should double the R&D tax credit rate from 20 to 40 percent for the regular credit and from 14 to 28 percent for the Alternative Simplified Credit, and restore full expensing of R&D expenditure.[86]

3.3 Scale the Materials Genome Initiative

Rapid developments in AI are accelerating innovation in advanced materials discovery and characterization. General purpose robotics and specially designed laboratory environments are already enabling automation of materials synthesis and testing processes.[87] The Materials Genome Initiative (MGI) was launched in 2011 as a moonshot program focused on infrastructure that American innovators need to discover, develop, manufacture, and deploy advanced materials.[88] The next step is bolstering MGI to work closer with industry to move newly discovered materials towards commercialization, which could help promote sustainability efforts and supply chain resilience.

Objective: Scale advanced materials discovery, characterization, and application processes for advanced manufacturing use-cases.

Method: The United States should substantially augment its capacity for materials synthesis through the MGI. In addition, a concerted effort is needed to establish public-private partnerships dedicated to accelerating advanced materials research, similar to the "Acceleration Consortium" based at the University of Toronto, which is developing "self-driving labs" that combine artificial intelligence, robotics, and advanced computing to discover new materials and molecules in a fraction of the usual time and cost.[89]

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[86] Such an approach would crowd-in additional private R&D dollars, helping U.S. firms regain the lead in size-adjusted R&D. See Trelysa Long & Robert D. Atkinson, Innovation Wars: How China Is Gaining on the United States in Corporate R&D, ITIF (2023). See a similar approach in S. 866, American Innovation and Jobs Act (2023); Andrew Lautz & Rachel Snyderman, Congress Is Running Out of Time to Fix a Critical R&D Tax Issue in 2023, Bipartisan Policy Center (2023).

[87] Tabassum Siddiqui, U of T receives $200-Million Grant to Support Acceleration Consortium's 'Self-Driving Labs' Research, University of Toronto News (2023).

[88] Materials Genome Initiative Strategic Plan, Subcommittee on the Materials Genome Initiative at iv (2021).

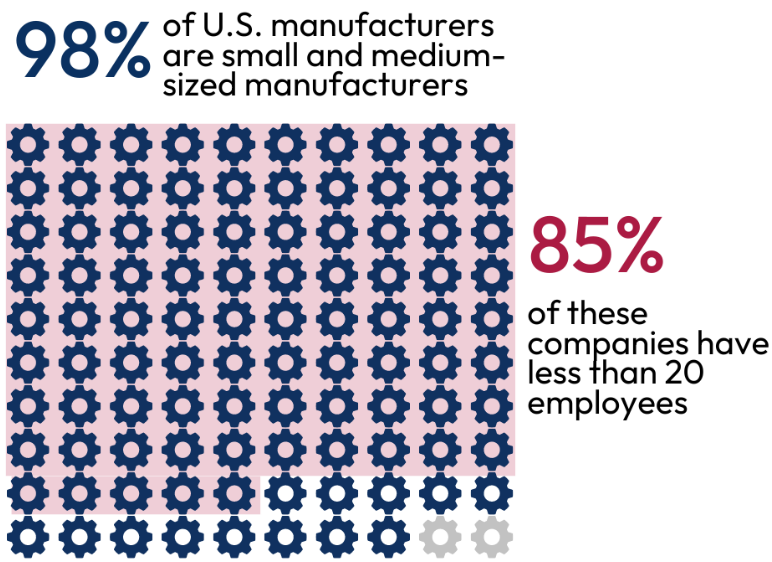
[89] Materials Genome Initiative Strategic Plan, Subcommittee on the Materials Genome Initiative (2021); Tabassum Siddiqui, U of T receives $200-million Grant to Support Acceleration Consortium's 'Self-Driving Labs' Research, University of Toronto News (2023).

ACTION PLAN RECOMMENDATION | 4 / 7

Promote: Accelerate Technology Adoption and Enable Scale-Up Capacity

4.1 Retool the Manufacturing Extension Partnership as a System Integrator
4.2 Close Capital Access Gaps for SMMs
4.3 Create a National Network for Additive Manufacturing
4.4 Deploy Large-Scale Financing Mechanisms to Bolster Domestic Production

SMMs face a range of uphill battles in adopting ADVM technologies. Some 98 percent of U.S. manufacturers are SMMs, representing approximately 300,000 manufacturers, making them the largest segment of the industrial ecosystem.[90] By all available measures, these firms lag behind major firms in adopting ADVM technologies, placing their competitiveness at risk. Only 12 percent of U.S. factories utilize robotic automation, for example, and only one-third are software-enabled and have cloud computing capabilities.[91] On the whole, U.S. SMMs report being stuck in "pilot purgatory" (i.e., unable to implement ADVM technologies at scale).[92] Graphic Source.[93]



[90] Towards Resilient Manufacturing Ecosystems Through Artificial Intelligence, National Institute of Standards and Technology at A-3, C-8 (2022).
[91] Elisabeth Reynolds, et al., Digital Technology and Supply Chain Resilience: A Call to Action to Accelerate U.S. Manufacturing Competitiveness, Massachusetts Business Roundtable & Manufacturing @ MIT at 2 (2023).
[92] Andres Aramayo-Prudencio, et al., Digital Manufacturing: Escaping Pilot Purgatory, McKinsey & Company (2018).
[93] Towards Resilient Manufacturing Ecosystems Through Artificial Intelligence, National Institute of Standards and Technology at A-3, C-8 (2022).

4.1 Retool the Manufacturing Extension Partnership (MEP) as a System Integrator

The MEP program, led by NIST, is a public-private partnership with centers in all 50 states (and Puerto Rico) that work with SMMs to improve business processes.[94] While the program has been successful, the United States significantly underinvests in MEP relative to both its own historical norms and compared to investments made by competitor nations.[95] MEP's budget has decreased by 13 percent since 1998 in inflation-adjusted dollars.[96] Moreover, the MEP program was established during the "quality revolution" of the late 1980s to help manufacturers compete primarily on cost and efficiency through "lean" processes and continuous improvement.[97] The MEP program should update its mission to reflect the imperative of facilitating the adoption of cutting-edge manufacturing technologies among SMMs.

Objective: Enable the MEP program to accelerate the deployment of ADVM technologies and digital manufacturing systems at scale.

Method: The United States should double annual funding for MEP from the current level of roughly $190 million,[98] positioning MEP centers to help SMMs deploy ADVM technologies, including technology packages under development by the manufacturing institutes.[99] The MEP program should update its mission, funding model, and key performance indicators to reflect the fact that the success of the program going forward will be measured in terms of its effectiveness in fostering the adoption of cutting-edge technologies among SMMs. In addition, MEP centers are distributed across all 50 states, which chafes against recent efforts to promote regional innovation ecosystems that are centered around technology hubs. Program evaluation efforts should consider how to optimally co-locate MEP centers with technology hubs.[100]

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[94] Manufacturing Extension Partnership, National Institute of Standards and Technology (last accessed 2024).
[95] Stephen Ezell, Why Manufacturing Digitalization Matters and How Countries Are Supporting It, Information Technology and Innovation Foundation at 49 (2018).
[96] MEP's FY2023 budget was approximately $188 million, compared to $113.5 million in FY1998. Pub. L. 117-328, Consolidated Appropriations Act, 2023, Title I (2022); Stephen Ezell, Policy Recommendations to Stimulate U.S. Manufacturing Innovation, Information Technology and Innovation Foundation at 9 (2020).
[97] 21st Century Manufacturing: The Role of the Manufacturing Extension Partnership Program, National Research Council at 45-54 (2013).
[98] Pub. L. 117–328, Consolidated Appropriations Act, 2023, Title I (2022); Ian Clay, Recent U.S. Manufacturing Employment Growth Hides the Sector's Abysmal Productivity Performance, Information Technology and Innovation Foundation (2023).
[99] William B. Bonvillian, Ensuring Manufacturing USA Reaches Its Potential, Day One Project at 7 (2021); Robert D. Atkinson, Time for a Federal-State National Economic Development Partnership, Information Technology and Innovation Foundation at 2 (2020).
[100] Cameron Davis, et al., Building Innovation Ecosystems: Accelerating Tech Hub Growth, McKinsey & Company (2023). The MEP National Network's 2023-2027 National Strategic Plan calls for transforming the MEP from a "system" of 51 individual centers to a "network" of collaborating centers and partners. MEP National Network 2023-2027 Strategic Plan, MEP National Network at 2 (2023).

4.2 Close Capital Access Gaps for SMMs

Apart from technical and administrative hurdles, SMMs face difficulties securing capital to finance systems upgrades and adopt cutting-edge technologies. The United States should leverage tax policy and credit and loan financing mechanisms to close capital access gaps for SMMS seeking to digitalize. In addition to investing in new equipment and digital systems, SMMs also need financial resources for staffing and training, and for hardware and software integration services. Increasing the adoption of ADVM technologies holds the potential to significantly bolster U.S. manufacturing productivity and increase U.S. industrial capacity.

Objective: Facilitate and de-risk the adoption of ADVM technologies among SMMs.

Method: Key actions could include:

- **Consolidate and scale capital access programs**. The United States should consolidate, leverage, and scale overlapping capital access and grant-making programs for SMMs to adopt advanced technologies. A range of such programs exist, including the Innovative Technologies in Manufacturing (ITM) program, the State Manufacturing Leadership program, and the Small Business Administration's (SBA) 7(a) Loan program.[101] The SBA's 7(a) program, in particular, should target capital access gaps for manufacturing firms.[102] In addition, the United States should further leverage innovative public-private financing mechanisms, such as the State Small Business Credit Initiative (SSBCI) and the Small Business Investment Company (SBIC) program, to promote technology adoption.[103]

- **Leverage tax policy to promote digital transformation**. Policymakers should consider investment tax credit (ITC) options to assist manufacturers seeking to digitalize their operations. One example could include a 25 percent credit on all capital expenditures, including capital equipment, machinery, and software, made above 75 percent of a base amount.[104] Policymakers could also consider permanently restoring first-year expensing on capital equipment, machinery, and software to accelerate the adoption of ADVM technologies, while also returning to an earnings before interest, tax, depreciation, and

[101] Innovative Technologies in Manufacturing: Commerce Has No Plans to Implement the Program, U.S. Government Accountability Office (2022); Stephen Ezell, Policy Recommendations to Stimulate U.S. Manufacturing Innovation, Information Technology and Innovation Foundation at 12 (2020).
[102] The SBA, the nation's primary mechanism for providing financial capital to small businesses to invest in capital equipment, does not give priority to manufacturing firms. Only 7.5 percent of SBA loans currently go to SMMs. Stephen Ezell, Policy Recommendations to Stimulate U.S. Manufacturing Innovation, Information Technology and Innovation Foundation at 13 (2020).
[103] SSBCI 2.0: A New Capital Tool for Revitalizing and Diversifying Manufacturing, The Century Foundation at 9 (2022); Pub. L. 117-2, American Rescue Plan Act of 2021 § 3301(2021); Readout of White House Convening to Announce New Small Businesses Investment Funds, The White House (2024).
[104] Stephen Ezell, Policy Recommendations to Stimulate U.S. Manufacturing Innovation, Information Technology and Innovation Foundation at 15 (2020).

amortization (EBITDA) based standard for interest deductibility, significantly increasing the competitiveness of U.S. firms.[105]

4.3 Create a National Network for Additive Manufacturing

The United States pioneered additive manufacturing technology and is poised to lead the world in its further development. Additive manufacturing capabilities unlock software-like design freedom across industries.[106] Apart from commercial benefits, DoD has placed significant emphasis on the potential of additive manufacturing technology to reduce critical supply chain vulnerabilities and enable fielding mission-critical hardware components in operational environments.[107] Although additive manufacturing adoption has increased in recent years, more must be done to support its application in real-world industrial operations.

Objective: De-risk the adoption of additive manufacturing capabilities for SMMs to add flexible, networked capacity to the U.S. industrial base.

Method: DoD should scale a national-level, distributed production network for additive manufacturing focused on SMM adoption. Such a network would provide SMMs with access to 3D printers and workforce training, in exchange for appropriate matching participation in a network that could be activated by DoD in times of emergency or in the event of a protracted conflict. Additional work would be needed to aggregate, select, and categorize additive manufacturing data across the network for supply chain management purposes, as well as set certification requirements for replacement parts produced via additive processes.[108]

4.4 Deploy Large-Scale Financing Mechanisms to Bolster Domestic Production

Manufacturing firms often find it difficult to scale up production onshore, due to diminished domestic production capacity, know-how, and lack of access to later-stage growth capital — even in the face of more public funding as well as the emergence of private-sector funds focused

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[105] Adam M. Michel, Expensing and the Taxation of Capital Investment, Cato Institute (2023); John Sprovieri, Congress Should Ease Tax Burden on Manufacturers, Assembly (2024). Two examples of this approach include H.R. 7024, Tax Relief for American Families and Workers Act of 2024 § 202 (2024) and S. 866, American Innovation and Jobs Act (2023).

[106] Andrew P. Hunter, et al., Achieving an Additive Manufacturing Breakthrough, Center for Strategic and International Studies (2021); Jörg Bromberger, et al., The Mainstreaming of Additive Manufacturing, McKinsey & Company (2022).

[107] Beth Reece, Leaders Outline Agency's Role in DOD Additive Manufacturing Capabilities, U.S. Department of Defense (2023).

[108] DoD could model their efforts on Project DIAMOnD, which is working to become the world's largest distributed manufacturing and emergency response network capable of producing physical objects on demand. See Project DIAMOnD, Project DIAMOnD (last accessed 2024).

on the industrial sector.[109] Moreover, innovative manufacturers have longer time horizons and larger capital needs than a typical software company, and the shorter-term time horizons of many private venture capital investors do not align with manufacturing lifecycle models. For these reasons, innovative manufacturing companies often scale up offshore. A study of capital-intensive hardware startups spun out of the Massachusetts Institute of Technology (MIT), for example, found that many startups moved pilot and later-stage production overseas because they could not find the capital or talent to scale in the United States, while foreign countries offered incentives such as more attractive capital, cheap land, and workforce training.[110]

Objective: Establish and augment authorities and resources, including through Advanced Market Commitments, to bolster domestic scale-up capacity for technology-intensive manufacturing firms.

Method: Key actions could include:

- **Establish public-private scale-up vehicles**. Policymakers have previously considered enacting the Scale-Up Manufacturing Investment Company (SUMIC) Act of 2015, which would have required the SBA to establish a scale-up manufacturing investment company, or SUMIC. The program would support debt and equity investments in qualifying manufacturing projects by providing leverage to participating private investment funds.[111] A similar effort may be called for today.

- **Utilize the Export-Import Bank of the United States (EXIM)**. EXIM should consider increasing transactions authorized under the Make More in America Initiative. In 2023, EXIM approved its first ever term-financing opportunities to support domestic manufacturing.[112] The Bank's existing Working Capital Loan Guarantee Program (WCLGP) and its Supply Chain Finance Guarantee (SCFG) program should also continue to be leveraged to support domestic scale-up activities.[113] Major U.S. exporters should use these programs to provide stability to their downstream suppliers, introducing resilience into the U.S. manufacturing ecosystem.

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[109] Peter L. Singer & William B. Bonvillian, "Innovation Orchards": Helping Tech Start-Ups Scale, Informational Technology and Innovation Foundation (2017). Public sector investments in scale-up are being made by the DOE Loan Program Office and the Office of Clean Energy Demonstration, as well as the Make More in America program led by EXIM. On private sector funds, see Trond Arne Undheim, The Top 40 Investors in Industrial Tech: How Investments in Transformative Solutions Using AI, Cloud, and Edge Act Like Probiotics for Manufacturing, Forbes (2022).
[110] See Elisabeth B. Reynolds, et al., Learning by Building: Complementary Assets and the Migration of Capabilities in U.S. Innovative Firms, MIT Industrial Performance Center at 27-29 (2013).
[111] See e.g., H.R. 3468 § 399, Scale-Up Manufacturing Investment Company Act of 2015.
[112] Export-Import Bank of the United States Approves First-Ever Term Financing for Domestic Manufacturing, Export-Import Bank of the United States (2023).
[113] EXIM Temporarily Expands Working Capital Guarantee Program, Export-Import Bank of the United States (2021).

- **Establish an Industrial Finance Corporation.** The United States could establish an Industrial Finance Corporation of the United States (IFCUS), modeled on the U.S. International Development Finance Corporation (DFC), that leverages public and private sector funding to support commercial scale up efforts for capital-intensive manufacturing enterprises.[114] Allies, partners, and adversaries, including Germany and China, leverage large-scale investment and development authorities to provide financing for advanced industries.[115]

ACTION PLAN RECOMMENDATION 5 / 7

Pushback: Defend U.S. Markets from PRC Overcapacity

5.1 Build Trade Alliances with Allies and Partners
5.2 Leverage Section 301 to Secure Access to Critical Technology Inputs
5.3 Utilize Section 232 to Build Resilient Supply Chains with Allies and Partners

Impending PRC overcapacity in advanced industries will require the United States to defend current and future technology battlegrounds. PRC net lending to manufacturing rose from just $63 billion in 2019 to over $680 billion in the first three quarters of 2023.[116] Systematic malpractice, as well as determined effort, has abetted the transfer of manufacturing capacity from the United States to China. Many of Beijing's tactics, including extensive subsidies, forced technology transfers, intellectual property theft, and forced labor, cannot be emulated by democratic market economies, leaving U.S. advanced industries struggling to survive in an asymmetric competition with "PRC Inc." Beijing's continued push to dominate the upper end of the value chain — including its push into the robotics market — threatens to further undermine the economic competitiveness of the United States and other market economies.

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[114] One example from a prior proposal to act on this recommendation is S. 2662, Industrial Finance Corporation Act; Robinson Meyer, The Bill That Could Truly, Actually Bring Back U.S. Manufacturing, The Atlantic (2021).
[115] Stephany Griffith-Jones, National Development Banks and Sustainable Infrastructure; The Case of KfW, Global Economic Governance Initiative (2016); David Adler, Guiding Finance: China's Strategy for Funding Advanced Manufacturing, American Affairs (2022).
[116] Keith Bradsher, More Semiconductors, Less Housing: China's New Economic Plan, The New York Times (2023).

5.1 Build Trade Alliances with Allies and Partners

Establishing long-term trade alliances with allies and partners will be essential for fortifying the U.S. manufacturing sector and leading in advanced industries of the future.[117] By deepening demand and output complementarities through strategic partnerships, the United States and its allies can create an open and robust trading ecosystem that progressively limits trade in strategic products with adversaries while enabling positive-sum gains. These measures would boost resilience to external shocks and anti-competitive economic tactics.

Objective: Build durable institutions that foster demand for U.S. advanced manufacturing products among allies and partners while lowering the cost of critical inputs.

Method: In order to create demand pooling effects and lower the cost of inputs for advanced industries, the United States should aim to negotiate free trade agreements (FTAs) with key allies and partners.[118] In some cases, the United States could negotiate more comprehensive agreements, while also pursuing more targeted approaches. Potential comprehensive partners include Taiwan, the United Kingdom, Japan, and other key defense allies in the Indo-Pacific. New trade agreements could borrow features of existing agreements with Australia.[119] Potential targets could include lowering the cost of imported critical minerals, steel, and microelectronics.

5.2 Leverage Section 301 to Secure Access to Critical Technology Inputs

The U.S. Government has several trade authorities and mechanisms at its disposal that can safeguard U.S. economic interests.[120] As the PRC continues to employ anti-competitive practices to cement its position as the world's premiere high-tech industrial producer, the targeted use of trade tools will become a necessary condition for building a sustainable U.S. advanced manufacturing ecosystem.

Objective: Insulate U.S. manufacturers from PRC overcapacity in critical technology sectors by utilizing U.S. Government trade authorities.

Method: The Executive Branch should continue to aggressively use existing high-impact trade instruments, in particular Section 301 of the Trade Act of 1974, to address a spectrum of unfair PRC manufacturing support practices.[121] Building on tariff increases announced in May 2024, the President could direct the United States Trade Representative (USTR) to continue restructuring

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[117] Liza Tobin & Rob Atkinson, The Missing Piece in America's Strategy for Techno-Economic Rivalry with China, Lawfare (2023).
[118] Clete R. Willems, It's Time for a US-Taiwan Free Trade Agreement, Atlantic Council (2024).
[119] Australia Free Trade Agreement, Office of the United States Trade Representative (last accessed 2024).
[120] Shayerah I. Akhtar, et al., U.S. Trade Policy: Background and Current Issues, Congressional Research Service (2024).
[121] Andres B. Schwarzenberg, Section 301 of the Trade Act of 1974, Congressional Research Service (2024).

existing duties to optimize for U.S. industrial strategy priorities, adjusting tariffs as needed as China's technology strategy evolves to seek unfair advantage in additional emerging sectors.[122] Higher duties should be considered for advanced manufacturing items such as IIoT devices and industrial robots, given their centrality to advanced manufacturing paradigms.

5.3 Utilize Section 232 to Build Resilient Supply Chains with Allies and Partners

Increasing the near-term resilience of critical supply chains is pivotal for ensuring the health of the U.S. manufacturing sector throughout the coming decade.[123] Building these supply chains in collaboration with allies and partners will help mitigate the economic and geopolitical risks posed by PRC advanced industry dominance and sustain reliable production capacity to withstand external shocks. Existing trade instruments can serve to incentivize the private sector to develop robust manufacturing supply networks with trusted allies and partners.

Objective: Secure supply chains by creating a 'preferential treatment' trade architecture with and among key allies and partners.

Method: The U.S. Government should consider leveraging essential security exemptions under Article XXI of the World Trade Organization (WTO) to create a two-tier system for imports.[124] In particular, the Executive Branch should utilize Section 232 to implement general duties that weaken the competitiveness of imports from the PRC and other bad actors while simultaneously constructing specific carve-outs for U.S. allies and partners.[125] In order to obtain a carveout, the U.S. Government could consider requiring partners to take reciprocal actions to address shared, systemic economic vulnerabilities caused by PRC excess capacity.[126] To mitigate frictions, the U.S. Government should combine any near-term usage of Section 232 with longer-term efforts to build rules-based trading agreements with democratic market economies.[127]

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[122] FACT SHEET: President Biden Takes Action to Protect American Workers and Businesses from China's Unfair Trade Practices, The White House (2024).
[123] Richard Baldwin, et al., Hidden Exposure: Measuring U.S. Supply Chain Reliance, National Bureau of Economic Research (2023).
[124] Article XXI: Security Exceptions, General Agreement on Tariffs and Trade (1994).
[125] Through the Trump administration's use of Section 232 to impose tariffs on steel and aluminum, and the subsequent Biden administration's creation of carve-outs for the European Union, the U.S. Government is beginning to build a two-tier system for the importation of steel. See, e.g., Philip Blenkinsop, EU Plans Anti-Subsidy Probe to Secure Steel Deal with U.S, Reuters (2023); Rachel F. Fefer, Section 232 of the Trade Expansion Act of 1962, Congressional Research Service (2022).
[126] See Philip Blenkinsop, EU Plans Anti-Subsidy Probe to Secure Steel Deal with U.S., Reuters (2023).
[127] See, e.g., Inu Manak & Helena Kopans-Johnson, In Green Steel Discussions, the United States Is Playing Dirty, Council on Foreign Relations (2023); Lode van de Hende & Eric White, EU Reaction to the US National Security Measures, Herbert Smith Freehills (2018).

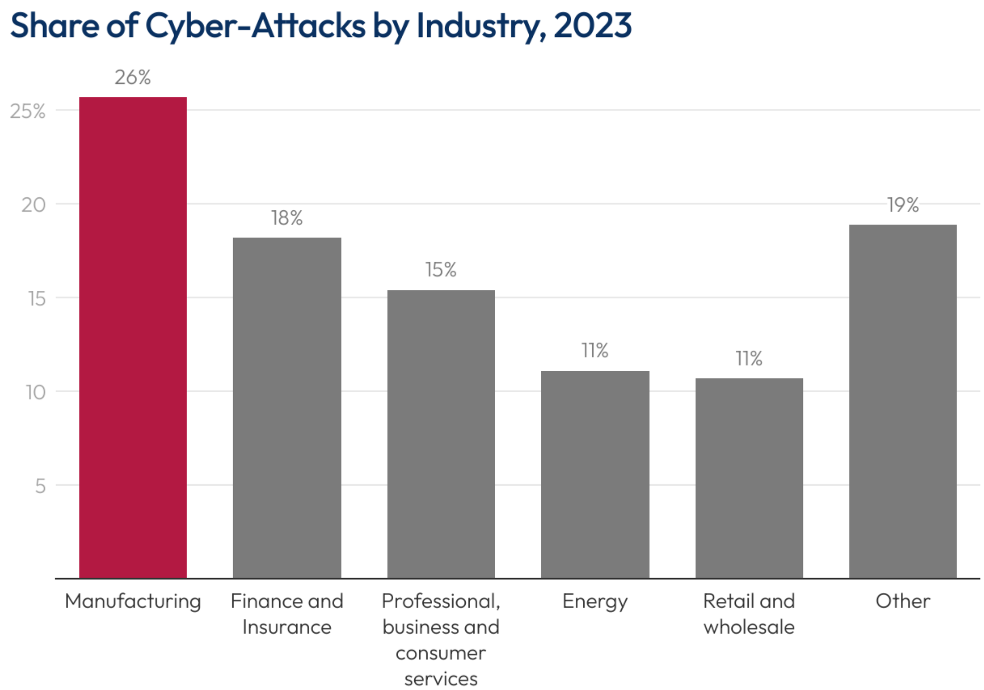
ACTION PLAN RECOMMENDATION	6 / 7

Defend: Cyber-Harden the Allied Industrial Base

6.1 Defend the Industrial Base with Automated Cyberdefenses
6.2 Develop Secure "Digital Threads" for Cyber-Physical Systems
6.3 Secure Supply Chains for Digital Infrastructure

Manufacturing has become the most attacked sector by a significant margin as of 2023.[128] Industrial control systems — the networks of hardware, software, and protocols that serve as the "brains" of cyber-physical systems, like factories and smart grids — were designed for use in secure, "air-gapped" environments that were not connected to the Internet.[129] By connecting and networking these devices together via IIoT systems, manufacturers are dramatically expanding the cyber attack surface. In addition, AI-enabled cyberattacks will become increasingly sophisticated and widespread in the coming years.[130] Current threats include polymorphic malware — which leverages AI to cover its tracks — and the use of generative AI to lower barriers to entry for attackers. The future may see deployment of autonomous AI agents for offensive cyber operations.[131] U.S. intelligence community leaders have warned that the PRC is both actively pursuing AI-enabled cyberweapons and targeting U.S. critical infrastructure, including advanced industrial facilities and systems.[132]

[128] X-Force Threat Intelligence Index 2023, IBM Security (2023).
[129] Amir Namavar Jahromi, AI-Enabled Cybersecurity Framework for Industrial Control Systems, University of Calgary at 4 (2022). A recent White House National Security Memorandum reaffirmed the Department of Homeland Security as the sector risk management agency for critical manufacturing. National Security Memorandum on Critical Infrastructure Security and Resilience, The White House (2024).
[130] Sanjay Aurora, Autonomous Cyber AI Is Revolutionizing Cyber Defense, CISO Mag (2019).
[131] Erwin Adi, et al., Artificial Intelligence for Cybersecurity: Offensive Tactics, Mitigation Techniques and Future Directions, Applied Cybersecurity & Internet Governance at 5-6 (2022).
[132] Joe Parkinson & Drew Hinshaw, FBI Director Says China Cyberattacks on U.S. Infrastructure Now at Unprecedented Scale, Wall Street Journal (2023).



Graphic Source.[133]

6.1 Defend the Industrial Base with Automated Cyberdefenses

Machine learning algorithms have been deployed within the past several years to augment cyber detection, but many of these tools remain fairly rudimentary. Keeping pace with cyberattacks supercharged by AI will require the United States and its allies and partners to deploy AI-enabled cyber defenses at scale.[134] Deploying trusted AI systems to defend critical infrastructure will require extensive testing: as the National Security Commission on Artificial Intelligence has noted, "AI-enabled cyber defenses will [require] large-scale, instrumented, and realistic testing, and they must be robust enough to withstand adversarial attacks."[135]

Objective: Deploy automated cyberdefenses at scale to secure the U.S. and allied industrial base.

Method: Key actions should include:

- **Modernize and scale testbeds for industrial control systems and IIoT**. NIST and DOE already boast impressive cyber testbed networks for industrial control systems, but these testbeds will need to be updated to deploy autonomous cyber defenses at scale. Next-

[133] Data from X-Force Threat Intelligence Index 2024, IBM.
[134] Andrew Lohn, et al., Autonomous Cyber Defense: A Roadmap from Lab to Ops, Center for Security and Emerging Technology & Centre for Emerging Technology & Security (2023).
[135] Final Report, National Security Commission on Artificial Intelligence at 51 (2021).

generation testbeds will need to incorporate characteristics of Autonomous Cyber Operations (ACO) gyms — sandboxes which allow for the training of AI, including by defending against attacks from adversarial AI systems.[136]

- **Work with U.S. allies, including NATO and the Five Eyes, to accelerate development, testing, and deployment**. U.S. allies and partners are positioned at the frontier of ACO. The United States should facilitate information sharing and work with allied governments to scale testbed resources and make them available to government entities and critical suppliers.

6.2 Develop Secure "Digital Threads" for Cyber-Physical Systems

The sheer number of software and hardware components that make up advanced manufacturing systems renders them uniquely vulnerable to bad actors. Sensors and IoT devices collect data on each step of the production line. Networking these datasets together allows firms to create a holistic view of the manufacturing process called a *digital thread* — a system for data collection and analysis that runs from the design and engineering stages all the way through deployment. "Supply chain attacks" exploit complexity by targeting the relationship between an entity and a trusted software vendor or hardware supplier.[137] Ultimately, addressing and preventing such attacks will require ensuring the provenance of each element of the supply chain for a cyber-physical system, from the hardware layer to the design tools, software libraries, and codebases used to create and sustain it.

Objective: Address and prevent attacks by developing public-private strategies for increased supply chain transparency, with an ultimate goal of guaranteeing the provenance of entire manufacturing systems.

Method: Relevant mission agencies should accelerate R&D and standardization for advanced supply chain provenance methodologies, such as the Supply Chain Integrity, Transparency, and Trust (SCITT) architecture and the cyber-physical passport concept being developed by CyManII, an MII developing next-generation cybersecurity approaches for cyber-physical systems.[138] Once these frameworks have reached maturity, the United States and its allies and partners should require the deployment of these methods for critical infrastructure sectors.[139]

[136] Sanyam Vyas, et al., Automated Cyber Defence: A Review, Proceedings of the ACM on Measurement and Analysis of Computing Systems (2023).
[137] Dina Temple-Raston, A 'Worst Nightmare' Cyberattack: the Untold Story of the SolarWinds Hack, NPR (2021).
[138] Howard Grimes, et al., Recommendations for Managing Cybersecurity Threats in the Manufacturing Sector, Cybersecurity Manufacturing Innovation Institute & Foley and Lardner (2023).
[139] National Security Memorandum on Critical Infrastructure Security and Resilience, The White House (2024).

6.3 Secure Supply Chains for Digital Infrastructure

As manufacturers adopt digital technologies, each element of the hardware stack — from IoT/OT and advanced networking components to data center and cloud compute environments — can present cybersecurity threat vectors, particularly if procured from adversarial nations.[140] Critical infrastructure in particular, including ports, water treatment facilities, energy grids, and manufacturing, are increasingly exposed to vulnerabilities as a result of the importation of compromised hardware.[141]

Objective: Identify and secure key digital infrastructure components necessary for advanced manufacturing and ensure access through domestic sources and trusted partners.

Method: Key actions should include:

- **Prioritize hardware security issues for international collaboration**. U.S. diplomats should continue to highlight the PRC's strategic prioritization of key digital infrastructure hardware components at international dialogues, such as the U.S.–EU Trade and Technology Council (TTC).[142] The TTC and other groupings of U.S. allies and partners should analyze key technology inputs up and down the advanced manufacturing technology stack and work collaboratively to deploy appropriate countermeasures.

- **Set and enforce hardware compliance standards**. NIST should consider requiring federal contractors to increase supply chain transparency by disclosing a hardware bill of materials. A software bill of materials (SBOM) discloses all open source and third-party components present in a software application, and the Biden Administration's 2021 Executive Order on Improving the Nation's Cybersecurity recommended requiring federal contractors to disclose an SBOM.[143] A hardware bill of materials (HBOM) would include detailed information on security validations, design intent, and country of origin for a piece of hardware, granting increased visibility and enabling authorities to mitigate and more quickly address attacks.[144]

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[140] Charles Parton, Dealing with the Threat of Chinese Cellular (IoT) Modules, Council on Geostrategy (2023).
[141] Dustin Volz, Espionage Probe Finds Communications Device on Chinese Cranes at U.S. Ports, Wall Street Journal (2024); Rebecca Beitsch, FBI: China Seeks to 'Wreak Havoc' by Targeting US Water, Electricity, The Hill (2024).
[142] U.S.-EU Summit Statement, The White House (2021).
[143] Executive Order on Improving the Nation's Cybersecurity, The White House (2021).
[144] Rick Switzer, The Next Pandemic Could Be Digital: Open Source Hardware and New Vectors of National Cybersecurity Risk, Special Competitive Studies Project at 20 (2022).

ACTION PLAN RECOMMENDATION | 7 / 7

Cultivate: Tackle Talent Shortages and Skills Gaps

7.1 Train One Million Manufacturing Workers with Cyber Skills by 2030
7.2 Establish an American Manufacturing Corps
7.3 Build a National Advanced Manufacturing Talent Marketplace
7.4 Reconceptualize the "Manufacturing" Workforce

Persistent labor shortages across the U.S. manufacturing sector are undermining efforts to lead in advanced industries of the future.[145] In June 2023, there were almost 600,000 manufacturing jobs waiting to be filled nationwide, with shortages projected to grow to 2.1 million unfilled jobs by 2030.[146] Despite the existence of many programs and initiatives, efforts to close manufacturing skills gaps and improve industrial workforce development pipelines have fallen short.[147] The U.S. dedicates only 0.1 percent of GDP to active labor-market programs across various industries, whereas other OECD governments dedicate, on average, 0.6 percent of GDP to these programs.[148]

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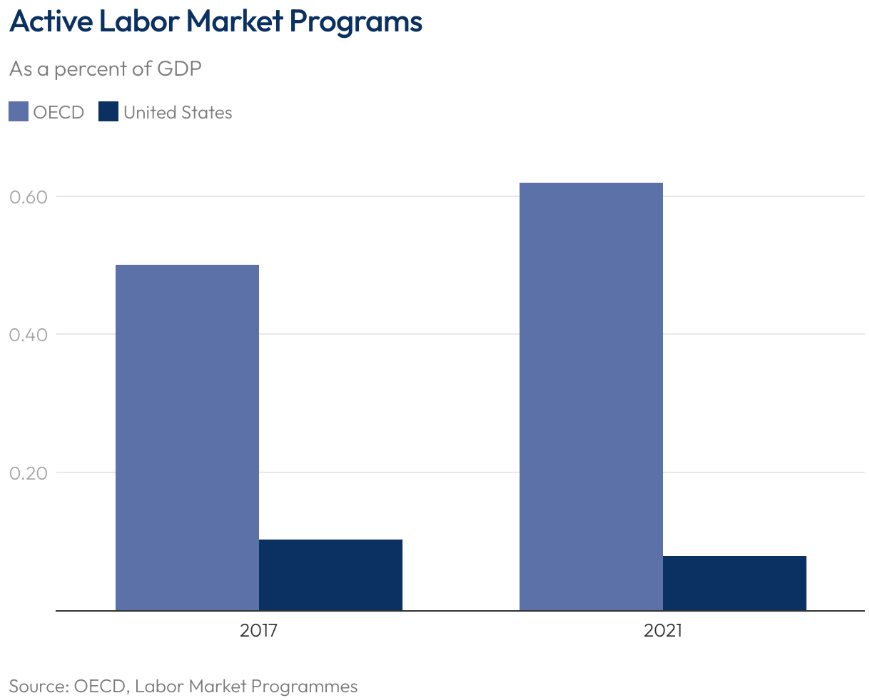
[145] National Defense Industrial Strategy, U.S. Department of Defense at 10 (2023); Garo Hovnanian, et al., Will a Labor Crunch Derail Plans to Upgrade US Infrastructure?, McKinsey Global Institute (2022).
[146] Kevin Stevick, Worker Shortage: Overcoming Workforce Challenges In Manufacturing, Forbes (2023); 2.1 Million Manufacturing Jobs Could Go Unfilled by 2030, National Association of Manufacturers Manufacturing Institute (2021).
[147] Advanced Technological Education, National Science Foundation (2021); Defense Department Launches Initiative to Boost U.S. Industrial Workforce, U.S. Department of Defense (2020).
[148] William B. Bonvillian, Restoring Leadership in U.S. Manufacturing, Day One Project at 4 (2020).



Graphic Source.[149]

7.1 Train One Million Manufacturing Workers with Cyber Skills by 2030

The United States faces a significant workforce shortage in cybersecurity, as in manufacturing more broadly. Talent is especially needed at the intersection of cybersecurity, industrial systems, and AI. Several Manufacturing USA institutes and leading universities and non-profits have established programs of note in this space. Building on the White House's recent efforts to develop cyber talent in the manufacturing sector, setting national-level objectives can help scale innovative cyber skills training.

Objective: Alleviate the skills gap at the intersection of cybersecurity and manufacturing by upskilling and training one million workers in manufacturing with cyber skills.

Method: The White House should elevate this milestone — which has been developed by DOE's manufacturing institute, CyManII — as a national goal.[150] To reach this goal on an accelerated timeline, the United States should aggressively resource DOE's roadmap and provide relevant agencies and public-private partnerships with additional funding. In addition, closer coordination will be needed between DHS, DOE, DoD, and NIST to track progress.

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[149] Data from Labor Market Programmes, OECD (last accessed 2024).
[150] Cybersecurity for Manufacturing Innovation: Strengthening and Securing U.S. Manufacturing with Innovations in Cybersecurity and Energy Efficiency, 2023 Annual Report, CyManII (2024).

7.2 Build a National Advanced Manufacturing Talent Marketplace

The United States needs to foster a more agile and responsive talent pipeline for developing the manufacturing workforce of the future. Companies, educational organizations (including community and technical colleges), and nonprofits are increasingly collaborating with the federal government to deepen national and regional education-to-workforce pipelines.[151] These efforts have accelerated under the current administration and are a promising sign, but work remains to be done.[152]

Objective: Consolidate talent marketplace resources to provide a unified platform for connecting advanced manufacturing job-seekers to employment opportunities.

Method: NIST, in partnership with the Department of Labor (DoL), should create a one-stop resource that allows talent to match with job opportunities in advanced industries. This resource should leverage best-in-breed platform solutions to deliver value and should be modeled on resources such as Cyberseek, a talent marketplace for connecting job seekers to in-demand cyber security jobs, as well as RoboticsCareers.org — the nation's first resource to connect manufacturers, workers, and job seekers with education programs to develop skills for careers in automation and robotics.[153]

7.3 Establish an American Manufacturing Corps

Revitalizing the U.S. manufacturing workforce will require cultivating, supporting, and inspiring the next generation of advanced industrial talent. The deindustrialization of the United States has not only made it difficult to attract and retain talent; it has brought negative stigma to manufacturing industries, compounding problems at generational scale.[154] Government and industry leaders must endeavor to restore dignity to manufacturing occupations in the national consciousness.

Objective: Inspire a new generation of talent to seek careers in the U.S. advanced manufacturing sector.

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[151] SME Announces New Initiative in Partnership with Community and Technical Colleges to Address the Manufacturing Industry's Workforce Shortage and Skills Gap Crisis, Society of Manufacturing Engineers (2023).
[152] FACT SHEET: To Launch Investing in America Tour, the Biden-Harris Administration Kicks Off Sprint to Catalyze Workforce Development Efforts for Advanced Manufacturing Jobs and Careers, The White House (2023); Revitalizing America's Manufacturing Workforce, Manufacturing USA (2023); Workforce Development for Manufacturers, Manufacturing Extension Partnership (2024).
[153] Cyberseek has impacted over 3 million cybersecurity professionals since its establishment in 2016. Deciphering the Cybersecurity Marketplace, Cyberseek (2023); see also ARM Institute Launches Job Matching Capabilities on RoboticsCareer.org, ARM Institute (2023); New Credential Engine & ARM Institute Partnership To Address Needs For Skills-Based Economy, Credential Engine (2022).
[154] Chad Moutray, The Manufacturing Experience: Compensation and Labour Market Competitiveness, Manufacturing Institute (2022); ARM Institute Robotics Technician Virtual Reality Assessment, ARM Institute (2024).

Method: In 2023, the Biden Administration launched an initiative inspired by the New Deal's Civilian Conservation Corps of the 1930s. The American Climate Corps (ACC) aims to offer employment opportunities to hundreds of thousands of young Americans, engaging communities across the nation by focusing on green jobs that contribute to environmental conservation and achieving climate resilience and sustainability goals for the nation.[155] The United States should launch a similar initiative — The American Manufacturing Corps (AMC) — aimed at enlisting the next generation of manufacturing talent in a national effort to revitalize the U.S. industrial commons and move manufacturing occupations to the forefront of national service-career consciousness. Design and implementation of an AMC could draw inspiration from previously proposed legislation to establish a National Manufacturing Guard — a reserve workforce of manufacturing supply chain experts trained to respond to crises of scarcity and assist efforts to scale-up production for critical goods and technologies.[156]

7.4 Reconceptualize the "Manufacturing" Workforce

The emergence of advanced production paradigms presents a unique opportunity for the United States to fundamentally reevaluate the manufacturing division of labor. Frontline workers of the future will need to function as general-purpose "technologists," serving both as engineers who are fluent in systems and processes, and as operators equipped to work with advanced machinery and equipment, including collaborative and autonomous robots.[157] Addressing the ADVM skills gap begins with revising occupational taxonomies to address the evolving role of workers in manufacturing environments characterized by cyber-physical convergence.

Objective: Reconceptualize ADVM workforce roles to account for the impact of emerging technologies on industrial processes.

Method: NIST, in partnership with NSF and the DoL, should identify roles and responsibilities that will define the ADVM occupations of tomorrow. The DoL should consider revising the current taxonomy of manufacturing occupations to reflect emerging technology trends that require workers to possess a mix of competencies, from working with programmable no-code interfaces to operating 3D printers.[158] NIST, in collaboration with relevant agencies and industry, academic, and non-profit partners, should also create a National Workforce

[155] FACT SHEET: Biden-Harris Administration Launches American Climate Corps to Train Young People in Clean Energy, Conservation, and Climate Resilience Skills, Create Good-Paying Jobs and Tackle the Climate Crisis, The White House (2023).
[156] H.R. 171 § 2, Resilient Manufacturing Task Force Act of 2021; S. 869, National Manufacturing Guard Act (2021).
[157] John Liu & William B. Bonvillian, The Technologist, Issues in Science and Technology (2024).
[158] John Liu & William B. Bonvillian, The Technologist, Issues in Science and Technology (2024). Developing this new taxonomy can build on previous efforts. See Lory Antonucci, et al., Partners in Connection: The Digital Workforce Succession in Manufacturing, ManpowerGroup & MxD (2017).

Framework for Advanced Manufacturing (NWFAM), similar to the NICE Framework for Cyber, which establishes a common cybersecurity workforce lexicon.[159]

[159] Rodney Petersen, et al., Workforce Framework for Cybersecurity (NICE Framework), National Institute of Standards and Technology (2020).