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Could an ARPA Help Resurrect US Manufacturing?

The United States will not regain its leadership in manufacturing by doing more of the same. The country must pursue new paradigms to invoke technological surprise and spur leaps in productivity.

The weakness of US manufacturing has become both a social and political issue. Supply chain shocks induced by the COVID-19 pandemic made the true costs of disinvestment in US manufacturing capability evident to American consumers. The war in Ukraine has shown the risks to national security from lack of manufacturing depth; it will take the United States years to replenish depleted stocks of missiles and artillery shells transferred to Ukraine. Today, China completely dominates the world market for drones, which have become a critical defense technology. And although lithium-ion batteries and solar photovoltaics were invented in the United States, China is now the dominant leader in both sectors.

Of course, this decline was happening long before the shocks of the last few years. US manufacturing has faced falling rates of productivity for 15 years. Between 2000 and 2010, the United States lost some 60,000 manufacturing plants and close to one-third of its manufacturing jobs. The social disruption caused by a hollowing of the manufacturing sector has been profound. The steep rise in economic inequality over recent decades has paralleled the decline of manufacturing. Once a solid pathway to the middle class, much of the opportunity offered by manufacturing careers has been erased. Since the United States abandoned most of its vocational educational system as a reform in the 1970s, the disconnect between work and school—the work/learn barrier—remains profound, and the sector has trouble finding the skilled workers it needs. And with escalating international competition, dwindling union membership, and a reduced employment base, the remaining manufacturing jobs are not as well paid as they once were.

Manufacturing is a more important part of the economy than current US policy acknowledges. Traditional approaches to manufacturing policy involve tax, trade, and currency valuation, which remain important. But without a focus on policies that incentivize manufacturing innovation, the country will not escape today's deficit. Though the United States remains a global leader in research and development, little of that capability is focused on manufacturing.

This is in part a legacy problem. During World War II, the United States developed mass production at a scale that was the envy of the world—no other nation was close. President Roosevelt's wartime science advisor, Vannevar Bush, never had to give manufacturing a thought in constructing the postwar innovation system because the country was so dominant. America was still catching up with European nations on basic science, so Bush's plan for US research and development was aimed at science—not production. He left manufacturing out of the equation, and since then there has been no national focus on manufacturing technologies and processes throughout the network of federal agencies that support R&D.

Unfortunately, industry also overlooked the value of investing in manufacturing innovation and continued to focus solely on mass production. US firms missed Japan's quality manufacturing revolution, which cost the country its leadership of the auto and consumer electronics sectors. To keep costs low, firms began shifting production offshore instead of innovating new efficiencies. Then China entered the World Trade Organization in 2001. China's rise was not simply based on low wages, but on innovation in improving production processes and creating rapid production scale-up, which the United States now cannot match. In 2023, nearly a third of the $218 billion US trade deficit for advanced technology products accounted for trade with China.

What would it take for US manufacturing to make a comeback? US policy, such as it is, has been treating the manufacturing problem with relatively short-term fixes, attempting to apply existing technologies to plug systemic leaks. But transformative changes are required to invigorate a production system that has been in decline for four decades, at all stages: R&D, prototyping, demonstration, testing, workforce education, and scale-up. There is not simply one valley of death for manufacturing technologies and processes—there is a complex labyrinth, with multiple blockages and many blind corners. A focused, longer-term approach is needed to correct systemic policy failures of the past.

A popular recommendation for fixing innovation-based woes in intelligence, energy, and health has been the creation of an ARPA—a clone of the Defense Advanced Research Project Agency at the Department of Defense (DOD). ARPAs are almost a cliché in American innovation policy—with nearly every thorny problem, policymakers call for an ARPA. But although an ARPA is hardly a magic wand, occasionally the country actually does need one. An ARPA that could foster technology advances that enable noteworthy gains in manufacturing productivity could be one of a suite of approaches to solving the production labyrinth.

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Do we need an ARPA for manufacturing?

Leveraging the United States' still-strong innovation system to make manufacturing more productive and competitive could be one way to fix the country's manufacturing problem. But leapfrogging from our current state will require not only new technologies but also new paradigms of innovation. Fundamental advances in manufacturing technology, like artificial intelligence for production analytics and small autonomous flexible robotics, must be nurtured through to the prototype stage to connect to the rest of the manufacturing ecosystem. Breakthroughs, not just incremental advances, are needed. The United States will not regain its leadership position on manufacturing just by doing more of the same things on manufacturing it does now. It must pursue entirely new paradigms in manufacturing that invoke technology surprise, such as through advanced materials for entirely new product properties or digital twins for remote system monitoring, repair, and operation.

The ARPA model fits this role. ARPAs are characteristically flat, nonhierarchical, and entrepreneurial agencies led by empowered project managers. They have no labs of their own but seek the very best research teams to pursue projects that focus on impact, not risk. ARPAs are largely autonomous and operate outside of bureaucratic controls, following a hybrid model that combines industry and academic researchers. The model accepts failures and orients research toward revolutionary breakthroughs.

An ARPA is not a magical fix for what ails the US manufacturing ecosystem, but it does offer one potentially transformative way to target a long-standing gap in government-industry innovation research. One way to think of innovation that starts in the lab and ends up in the market is through the technology readiness levels, or TRLs, which are numbered 1 through 9. ARPA research projects typically focus on early-stage research to proof-of-concept functions up to prototype development (TRLs 1 through 3). As noted, the federal research agencies supporting R&D in these stages have not built out significant portfolios for manufacturing technologies. This research gap impedes the effectiveness of the 17 advanced manufacturing institutes that were created to advance applied manufacturing technology—the stages from validating a working prototype to introducing it into an operational setting (TRLs 4 through 7). Funding for the institutes, which serve as hubs of engagement for industry, universities, and state and local economic development programs, is too low. But even with adequate funding, the institutes need the feed-in of ongoing advances in earlier stages of research to nourish new manufacturing technologies into initial production. An ARPA for manufacturing could potentially address this gap.

What would a manufacturing ARPA look like?

DARPA and its clones are unique among other R&D agencies because ARPAs prioritize three critical components. First, ARPAs follow the "island-bridge" model—the agency should be independent enough to do great, high-risk research, but linked closely enough to the "mainland" political decisionmakers who can help take steps to transfer technology breakthroughs into the wider world. Second, ARPAs need to be able to command the resources and ability to transition the technology into implementation. DARPA makes technology transition happen by leveraging the massive acquisition budgets of the military services to move the technologies DARPA is prototyping through demonstration, testing, production, and product introduction. (The DARPA clones not linked to procurement budgets have faced challenges with this.) And third, ARPAs are steeped in a culture of boldness and risk tolerance that is truly unique within the research ecosystem. Breakthroughs require risk-taking; there are few breakthroughs without it.

An ARPA for manufacturing needs to successfully replicate these three features—but that will depend on where it is situated in the federal government. For example, one obvious place for it would be in the Department of Commerce, which houses the National Institute for Standards and Technology (NIST), an R&D agency with a history of industry research collaborations. NIST also houses the Manufacturing Extension Partnership (MEP) that brings manufacturing process improvements to small and midsized manufacturers, and an Office of Advanced Manufacturing that oversees and supports one current and two planned manufacturing institutes. In addition, NIST oversees the implementation of the CHIPS and Science Act to reestablish US leadership in advanced semiconductor production. If an ARPA-M reported to the secretary of commerce, it could solve the island-bridge challenge. However, Commerce has no procurement budget and no clear pathway to further technology transition. For an ARPA-M to work within Commerce, it would have to acquire financing authority and other extensive resources to facilitate technology transition. In addition, the agency lacks an ARPA culture, which would have to be nurtured.

An ARPA-M might find more success within DOD. The agency has a major stake in the defense industrial base, as well as in the nation's overall industrial base, on which its defense capabilities are highly dependent. In fact, a strong argument can be made that DOD must strengthen production capability to restore the arsenal of democracy. The 10 major defense contractors of the 1980s have dwindled to five, reducing capacity and competition. The value of the National Defense Stockpile, which totaled over $9 billion in 1989, has fallen to less than $1 billion today—it is no longer a functional reserve. Even with a planned surge in production to restore a wide range of military stocks depleted in the Ukraine war, replacements will take years. The United States currently can only replace about 12% per year of the stock of artillery shells it has transferred to Ukraine. Missile replacement is particularly problematic. Transferred stocks of Javelin antitank missiles will take over five years to replace; HIMARS guided rockets will take over two years to replace; and Stinger antiaircraft missiles will take between six and 18 years to replace. Advanced manufacturing has the potential to deliver significant new production efficiency—and corresponding savings—for DOD, which struggles to obtain the defense technologies it needs.

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To the extent that advanced manufacturing can lead to improvement in overall US industrial capability, that is a major plus for the agency. In addition, DOD has considerable experience with the DARPA model. It would have no problem implementing an island-bridge model, with an ARPA-M reporting to the secretary of defense. Since it is home to DARPA, it understands the DARPA culture and can draw directly on DARPA advice and personnel for its implementation. And the DOD's significant procurement spending could potentially transition manufacturing technologies out of the defense arena and into the wider manufacturing ecosystem.

DOD has a history of doing this. For example, computer numerically controlled (CNC) machining was developed in 1958 by inventor John Parsons and researchers at the Massachusetts Institute of Technology. CNC enabled precision in manufacturing machining, which was necessary for DOD's critical missile programs. So the department leveraged its procurement spending to require contractors to use CNC equipment, and then bought and leased it at low cost to contractors to enable the shift. It thus sponsored the development and demonstration of CNC machines, created their initial market, and paved the way for their widespread acceptance in industry. Thanks to this DOD technology push, CNC machining is now pervasive. Today, DOD retains the extensive powers of the Defense Production Act (DPA), giving it the ability to intervene in markets to get the national security technologies it needs. Application of DOD's procurement budget and DPA powers could be a model for adopting advanced manufacturing technologies at scale.

A final option would be to create a manufacturing mission as a new office within DARPA itself. DARPA has created special-purpose offices within its structure in the past for particular objectives, such as its Adaptive Capabilities Office (ACO), which works on pathways to address critical national security challenges. Clearly, the strength of the defense (and national) industrial base falls in that category. Recently, ACO has begun exploring the question of how to support the industrial base by addressing DOD's ability to rapidly scale up crisis production of key defense products. Two other DARPA offices—the Information Innovation Office and the Strategic Technology Office—have also begun looking at manufacturing challenges.

Opportunities to create a manufacturing transformation

No matter the design or location, it's not enough to do only breakthrough research on advanced manufacturing technologies in an ARPA-like entity. Technology development relies on a chain of innovation, and every link in the chain must be strong. An ARPA for manufacturing will be successful only if it is one component of a larger ecosystem that addresses research, policy, finance, industry collaboration, and worker education.

To be truly transformative, an ARPA-M needs strategic leadership and support and a related network of programs. If it produces innovations alone, without these other vital features, it will simply join the debris of previous well-intentioned but underpowered efforts. To address the series of weak points in the chain of innovation for American manufacturing, policymakers need to seize opportunities to improve the existing innovation landscape.

First, decisionmakers need to put someone in charge. There are diverse efforts at various agencies that together provide a significant toolset for manufacturing advances, but interagency coordination is usually a contradiction in terms. The pieces will not self-assemble. Leadership is required, and a White House office for manufacturing is the logical coordination source. Such an office could lead an effort to identify and map supply chain gaps and technology vulnerabilities, which is needed for production of key technologies. Likewise, a coordinating office could conduct a comparative manufacturing technology assessment across competitor nations and corresponding projects to apply incentives for technology catch-up and filling supply chain gaps.

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Another area of opportunity lies with the 17 advanced manufacturing institutes, which are delivering a number of successes today but are not funded at the necessary levels. Manufacturing is a $2.5 trillion a year sector; a $200 million a year program is not going to transform it. Funding the institutes at their original support levels or more would enable them to maintain their workforce programs and outreach to small and midsize firms—a crucial part of heartland manufacturing transformation. Because this will be a long process, the five-year term limits on the institutes should be removed and replaced with reviews and conditional extensions after the first five-year term. Also needed is a more cohesive network across the institutes—another originally intended aspect of Manufacturing USA (originally called the National Network of Manufacturing Innovation), which has not been realized to the necessary extent. Each institute pursues a separate technology strand—from robotics to digital production to photonics. But manufacturers, particularly smaller ones, don't want stovepiped technologies; they need tested packages of technologies that are interactive and work together, and can be more easily adopted by industry. Cross-institute networking to produce these packages will help private-sector participants build true "factories of the future," integrating multiple advanced manufacturing technologies.

To smooth the path for industry adoption of advanced manufacturing technologies, the manufacturing institutes should also provide full testing and demonstration. Some institutes have been able to build these facilities, but they must be expanded and improved across all 17. They also should provide coordinated testing across technologies: New industrial robotics need to be shown to work with digital production technology, for example. In addition, a technology certification system should be set up to certify and validate new technologies to help speed market introduction. Part of Germany's historic success in manufacturing is its Fraunhofer system of collaborations between firms and engineering universities. Famously, the Fraunhofer Institutes have a lab that assists in these steps of demonstration, testing, and technology certification, which provides a potential model of what the Manufacturing USA institutes should aim for.

Two other significant gaps require attention. The first is in financing the introduction of manufacturing technologies, which can be addressed by seizing opportunities in our current system. Venture capital has been a major source of financing for US innovation, but its focus is now overwhelmingly on software, biotech, and various services sectors. It largely dropped "hard tech"—innovations that must be manufactured—because the risk is longer term. This means that the key US mechanism for scaling up new industries is missing. Meanwhile, China provides massive financial support for manufacturing scale-up, a key to its success, in the range of $500 billion a year. The United States has nothing comparable.

One way to fix this is to shift federal tax incentives for venture capital to drive private sector capital into advanced manufacturing scale-up. Another opportunity can be found in DOD's procurement budget, which could be applied to scale up demonstrated advanced manufacturing technologies. Following on its success in bringing CNC equipment into greater use, DOD could create incentives and leasing schemes to get its contractors to adopt new advanced manufacturing technologies. Capitalizing on the synergy between DOD procurement and venture capital might remove some of the bottlenecks in shifting manufacturers toward transformative technologies and processes.

The other gap that must be addressed has to do with workforce education, which will require attention across multiple government departments and schools throughout the country. Rebuilding opportunities for the technical workforce requires a strong manufacturing apprenticeship program (including youth apprenticeships starting in high school). Development of advanced manufacturing curricula and offerings at community colleges is also required. Working with industry consortia to develop education collaborations with community colleges and universities will take deliberate investment and partnership.

The country also needs a new occupational category: the technologist. While engineers work on design upstairs, downstairs on the factory floor technicians are tied to lifetime careers around particular machines and skills, like CNC machining or welding. In addition to engineers and technicians, advanced manufacturing will require technologists who understand both roles—able to integrate the machines, apply data analytics to operate them as high-productivity systems, and introduce new manufacturing technologies. Industry and community colleges need to engage together to create this new career path that will be a key to implementing advanced manufacturing.

An ARPA for manufacturing could provide the missing link in the chain of US manufacturing innovation for development and prototyping, but it would be just one piece in the US manufacturing puzzle. The United States cannot afford inaction or half measures. While other nations, including Germany, Japan, Korea, Taiwan, and China, introduced manufacturing-led innovation, America failed to keep pace. With machine learning and AI, robotics, digital production, new materials, biofabrication, and a host of other advances, the new technological age at hand could transform the production process, and the United States can't afford to lose out again.

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RECOMMENDED READING

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