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ITIF Comments Responding to Administration RFI for National Strategic Plan for Advanced Manufacturing

Submitted to the

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By: Stephen Ezell, Robert Atkinson, and David Hart

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The Information Technology and Innovation Foundation (ITIF) is a nonprofit, nonpartisan research and educational institute focusing on the intersection of technological innovation and public policy and which has been recognized as the world's leading science and technology policy think tank. ITIF is pleased to provide feedback in response to the administration's call for comments related to seven key questions toward the development of a National Strategic Plan for Advanced Manufacturing.

Why Manufacturing Matters

A healthy advanced manufacturing sector matters for a number of reasons. One is jobs. Despite losses in the 2000s, U.S. manufacturing employs 12.6 million workers. Moreover, manufacturing jobs have a high multiplier; in fact, for every manufacturing job 3.4 full-time jobs are created elsewhere in the United States to support manufacturers' efforts.[1] Similarly, manufacturing continues to create a significant economic multiplier for the U.S. economy, with the sector generating $3.60 of value-added elsewhere in the U.S. economy for each $1.00 of value added by domestic manufacturing.[2]

Manufacturing also represents the principal source of U.S. R&D and innovation activity. Manufacturing firms perform approximately 70 percent of U.S. industry R&D, despite the fact that manufacturing accounts for only about 11 percent of the economy.[3] Manufacturing firms employ over 60 percent of research and development (R&D) scientists and engineers in industry.[4] Further, scientists and engineers accounted for 7.8 percent of the manufacturing labor force in 2011, a share that is more than twice as large as found across the rest of the economy.[5] Manufacturing firms have also demonstrated innovation rates almost three times greater than non-manufacturing firms.[6] In other words, if America loses its manufacturing sectors, it loses key drivers of its innovation economy. Manufacturing is also a key enabler of the U.S. defense industrial base, and ensuring the capability to remain on the cutting edge of innovation will be key enabler of future U.S. defense advantage over our adversaries.

But perhaps the most important reason the United States needs a healthy manufacturing base is because it's the principal way for our nation to stop running chronic trade deficits. While some erroneously assert that trade deficits don't matter, or that they are the result of low national savings rates, the reality is that the massive bill America runs up every year by buying more imports than selling exports will have to be paid eventually when foreign nations demand payment in real goods and services, not in Treasury Bills.[7] And while some of the effects of America's weaker manufacturing base have been endured by the six million manufacturing workers who lost their jobs in the 2000s, those effects will be felt most keenly in the future in the form of a trade debt that future generations will have to pay off by producing more than they consume and exporting the difference.

It's as simple as this: every import Americans consume greater than what we export is one that a future generation will have to pay for in the form of reduced consumption of real goods and services and a future trade surplus. Thus, the trade deficit represents a hidden tax on the next generation of Americans. The reality is that the United States will have to significantly boost its manufacturing exports to balance its trade in order to avoid passing on unsustainable debts to future generations. Ultimately, without a robust manufacturing sector, it's simply impossible for almost any nation, unless it's endowed with oil or other natural resources, to balance its trade—and the United States is no exception.

Why Markets Alone Are Insufficient

ITIF commends the Trump administration and the Office of Science and Technology Policy (OSTP) for developing a National Strategic Plan for Advanced Manufacturing. Doing so matters greatly, for the reality is that manufacturing activity is subject to a number of market failures that validate a government's role in charting a path toward bolstering the global competitiveness and innovation capacity of its manufacturing enterprises and industries, as ITIF writes in both the book *Innovation Economics: The Race for Global Advantage* and its report "The Case for a National Manufacturing Strategy."[8]

For instance, high levels of risk, expense, and differing time horizons limit the development of complex new technology platforms. Even "rational" companies are reluctant to invest in next-generation technologies, especially when it involves high levels of risk and exceedingly lengthy research and development timeframes. Indeed, the reason the Defense Advanced Research Projects Agency (DARPA) and not the private sector created the "Internet" was because the sums required were significant and the nascent technology was so far from potential commercialization that companies were unable to foresee how they could monetize potential investments. This same corporate reticence to invest in the risky future evident in the Internet's development pertains today to a range of emerging infrastructure-based technologies, including nanotechnology, robotics, and meta-materials. At the same time, a related challenge is that "the complex multidisciplinary basis for new technologies demands the availability of technology platforms before efficient applied R&D leading to commercial innovation can occur."[9] In other words, the levels of investment required to research and to develop emerging technologies is so great that in many instances the private sector cannot support the effort alone, and therefore "government must increasingly assume the role of partner with industry in managing technology research projects."[10]

At the same time, capital market failures have caused private financing of R&D to shift away from innovation-based and entrepreneurial efforts. One manifestation of this is that private financing of R&D in the United States has shifted away from more entrepreneurial and early-stage research efforts, largely because of decisionmakers' shorter time horizons.[11] As ITIF documents in *Innovation Economics*, corporate-funded R&D is increasingly less focused on earlier-stage research and more on later-stage, development-related activities.

This short-termism also leads manufacturers to underinvest in needed new capital equipment. Unfortunately, as ITIF writes in "Restoring America's Lagging Investment in Capital Goods," American businesses' investments in new capital equipment, software, and structures have slowed significantly in recent decades. While such investment grew by 2.7 percent per year on average during the 1980s, and by 5.2 percent annually during the 1990s, from 2000 to 2011, U.S. businesses' investments in new capital equipment, software, and structures grew by just 0.5 percent. Moreover, as a share of gross domestic product (GDP), U.S. business investment has declined by over 3 percentage points since the 1980s.[12]

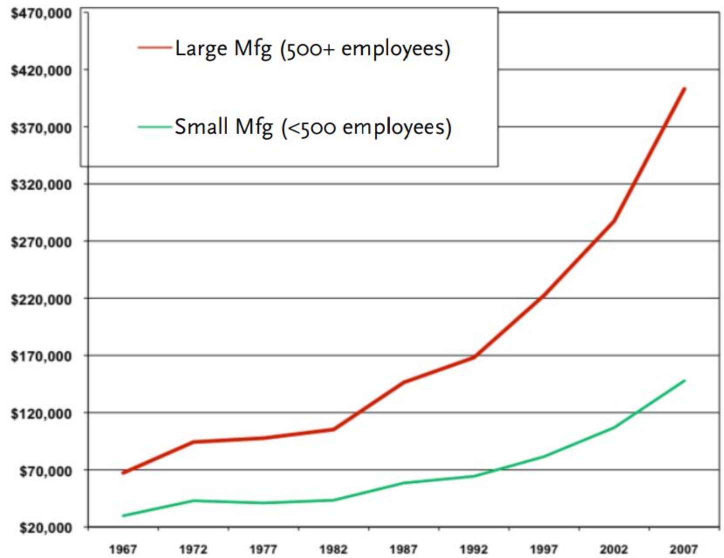
A major part of the reason firms underinvest in activities such as new capital equipment or more R&D is because, since they cannot capture all the benefits of their own innovative activity, they will produce less innovation activity than society needs, which is why there's a compelling public policy rationale for instruments like incentives for capital equipment investment (e.g., first-year expensing) or generous R&D tax credits. Economists have long understood that free markets will underperform in the presence of positive externalities and that smart public policies, like first-year expensing and the R&D credit, effectively correct market failures.

Another area of market failure pertains to enterprises' investment in worker skills. For instance, corporate investment in training as a share of GDP declined from more than half a percent in 2000 down to one-third of a percent in 2013.[13] Further, as the *Economic Report of the President* finds, the proportion of workers that received employer-sponsored training dropped 42 percent between 1996 and 2008.[14] Moreover, as a share of GDP, the United States invests just one-sixth in active labor market support policies than does peer Organization for Economic Cooperation and Development (OECD) nations on average, and one-twelfth the level of leading countries such as Denmark or Sweden.[15] ITIF proposes a number of policy remedies to enterprise and societal underinvestment in workforce skills development—including establishing a knowledge tax credit that would allow firms to take a tax credit for expenditures on both research and development and workforce training—in its report "How to Reform Worker-Training and Adjustment Policies for an Era of Technological Change."[16]

A related market failure relates to the fact that U.S. manufacturing is a traded sector (i.e., it comprises sectors competing in international marketplaces). If foreign manufacturers take market share from a manufacturer in the United States, not only is the domestic manufacturer hurt, but so too are its suppliers and the companies that depend on the spending of the manufacturing workers. Economists refer to this as the multiplier effect. In contrast, if a barber shop or grocery store goes out of business in a community, another one will more or less automatically emerge (or an existing one expand) due to consumer demand. This traded-ness of manufacturing is why virtually every state, whether led by a Republican or Democratic governor, has policies to support traded sectors, especially those in advanced manufacturing.

Another market failure pertains to the ability of small- to medium-sized manufacturers (SMMs) to adopt modern, best manufacturing practices and processes. Despite their importance, SMMs often lack the information networks, technical skills, and resources available to larger firms. Largely because of this, a substantial productivity gap exists between large and small manufacturers. This gap is seen in virtually all countries and has been growing over time. For example, on average in the United States, value-added per employee in SMMs was about 80 percent of that of large establishments in the 1960s, but by the late 1990s, value-added per employee in SMMs was on average less than 60 percent of large establishments (figure 1).[17] Likewise, "UK manufacturing SMMs are comparatively weak performers in important areas such as productivity and market-winning dimensions."[18] These productivity gaps occur in part because SMMs tend to invest less in equipment and are less likely to adopt new business and manufacturing practices than are large firms.[19] But they also occur because small manufacturers often simply lack the resources, scale, experience, or wherewithal to stay abreast of the latest emerging technologies, manufacturing processes, or business management practices. Thus, a critical role countries' manufacturing extension services play is to close this knowledge and best practices gap between small and large manufacturers.[20]

Figure 1: The Productivity Gap Between Small and Large Manufacturing Establishments is Growing, 1967-2007[21]



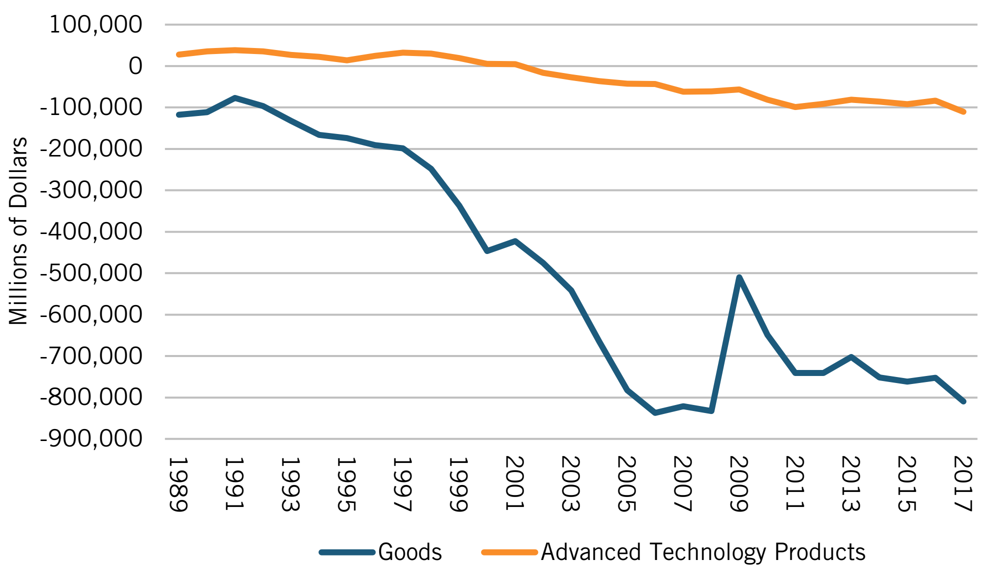
Finally, while not exactly a market failure, the fact that other nations are putting in place advanced manufacturing strategies means that if the United States does not respond with its own strategy, firms in the United States will be hurt. U.S. industries are often the explicit and named *targets* of competitor nations' manufacturing strategies, such as China's $330 billion "Made in China 2025" strategy. This means both that their success is by no means assured and also that they are vulnerable to countries' unfair, mercantilist trade practices, which requires America to respond with both effective market opening and trade enforcement policies. For instance, as ITIF writes in "Stopping China's Mercantilism: A Doctrine of Constructive, Alliance-Backed Confrontation," what's at stake in U.S.-China trade and economic relations is nothing less than the survival, let alone the vitality, of America's advanced-technology industries.[22] With China, the contest in the 1980s and 1990s was about low- and mid-tech manufacturing, in which Chinese policies hollowed out many sectors of traditional U.S. manufacturing; whereas the current contest revolves around which country is going to lead the future in advanced-technology industries. For instance, China has committed $160 billion to develop a completely closed-loop semiconductor ecosystem, with the avowed goal of reducing the country's imports of U.S. semiconductors by half by 2025 and eliminating them entirely by 2035 (all the while China expects unfettered access to international markets for exports of its own products).[23] When international markets aren't working properly, particularly when leading competitor nations are wedded to a version of state-led capitalism that repudiates rules-based, market-based principles, concerted policy action to ensure global level playing fields for U.S. producers is demanded.

Responses to Specific Questions Asked in the RFI:

1. **In priority order, what should be the near-term and long-term objectives for advanced manufacturing, including R&D objectives, the anticipated time frame for achieving the objectives, and the metrics for use in assessing progress toward the objectives?**

As noted, ITIF believes **the primary objective should be to turn America's trade deficit in advanced-manufacturing products into a sizeable trade surplus**. The United States runs undesirable trade deficits in both manufactured goods broadly and advanced technology products specifically. Indeed, the United States now runs a trade deficit of approximately $800 billion dollars per year in manufactured goods. And even in advanced technology products, which should be a national strength, the United States ran a deficit of over $110 billion in 2017 (and roughly that amount in most years since 2009), as figure 2 shows. **The Trump administration should establish a goal of achieving a trade surplus in advanced technology products of at least $200 billion annually.** This objective should be accomplished within the next 5 to 10 years. But it should be accomplished principally by helping U.S. firms boost their innovation and productivity levels. Reducing the trade surplus through tariffs or other barriers to trade will not significantly boost U.S. economic growth.

Figure 2: U.S. Trade Balance in Manufactured Goods and Advanced Technology Products, 1989-2017[24]



With regard to R&D, rather than having the government define specific R&D objectives ahead of time, a better approach would be to allow industry to define the R&D objectives it views as essential, especially ones industry considers important enough to contribute shared investment into an expanded, increasingly industry-directed Manufacturing USA program. Experience has shown that the Institutes have attracted significant amounts of private-sector investment, often on the order of two to three times the amount of federal investment; such commitments from the private sector are likely to be even greater if industry increasingly leads selection and development of the Institutes.

With regard to the five goals recently articulated by the Department of Energy (DOE) Advanced Manufacturing Office (AMO) as part of its 2016 Multi-year Program Plan (MYPP), ITIF would rank the importance of those five stated goals in the following order:

1. Improve the productivity and energy efficiency of U.S. manufacturing;
2. Transition DOE-supported innovative technologies and practices into U.S. manufacturing capabilities;
3. Reduce lifecycle energy and resource impacts of manufactured goods;
4. Leverage diverse domestic energy resources in U.S. manufacturing, while strengthening environmental stewardship;
5. Strengthen and advance the U.S. manufacturing workforce.[25]

We suggest this ordering because, in our view, boosting productivity and innovation should be the major goals of U.S. advanced manufacturing policies.

2. How can Federal agencies and federally funded R&D centers supporting advanced manufacturing R&D foster the transfer of R&D results into new manufacturing technologies and United States-based manufacturing of new products and processes for the benefit of society to ensure national, energy, and economic security? What role can public-private partnerships play, and how should they be structured for maximum impact?

The administration should fully implement the Manufacturing Engineering Education Grant (MEEG) program, as the Department of Defense (DOD) was directed by Section 215 of the 2017 National Defense Authorization Act (NDAA). The intent of the legislation is to assist universities (or academic-industry consortia) in revamping their engineering programs to focus much more on manufacturing engineering and in particular on work that is more relevant to industry. This would include more joint industry-university research projects, more student training that incorporates manufacturing experiences through co-ops or other programs, and a Ph.D. education program focused on turning out more engineering graduates who work in industry.[26] As Georgia Tech has done, it could also include the appointment of a Chief Manufacturing Officer to oversee universities' interdisciplinary manufacturing programs and ascertain how they can maximize their impact on economic development. The 2017 NDAA allocated $10 million to get the MEEG program stood-up, with that initial investment a starting point toward a program blossoming into the hundreds of millions of dollars, as ITIF and other think tanks have advocated.[27]

The U.S. innovation system could realize much more leverage from its network of Engineering Research Centers (ERCs) and Industry/University Cooperative Research Centers (I/UCRCs). Unfortunately, both programs are quite small, and the ERCs especially engage with industry only weakly and too often conduct academic research of limited relevance to industry.[28] Very few ERCs are truly engaged in engineering R&D and transitioning technologies to the marketplace as opposed to simply producing more journal papers. Both programs need considerably more funding, which should be focused on centers addressing advanced manufacturing technology issues, which could be funded by transferring funds from other National Science Foundation (NSF) programs to these. In addition, **the administration should require NSF to give much higher priority in allocating awards to the share of industry funding contributed. It should also advocate for a policy change that federal funding for all ERCs be matched at least 40 percent by industry by 2018.** ERCs failing to attract at least a 40 percent industry match within five years should lose their federal funding.

Likewise, **the administration should continue to grow the set of I/UCRCs focused on advanced manufacturing-related technologies.** There are currently 83 I/UCRCs, which represent partnerships between universities and industry, featuring industrially relevant fundamental research, industrial support of and collaboration in research and education, and direct transfer of university-developed ideas, research results, and technology to U.S. industry to improve its competitive posture in global markets.[29] 2018 National Science Foundation funding for the I/UCRC program, at $12.5 million (though an increase of $1.74 million from the prior year), is still well below the level warranted for such an impactful program.[30] ITIF has called for increasing I/UCRC program funding to at least $50 million per year. Likewise, funding for the ERCs, which NSF requested $36.2 billion for in FY 2018 form Congress, should be tripled to a level closer to $100 million annually.[31]

More broadly, **NSF should increase both the level and share of its funding flowing into engineering-related programs broadly and manufacturing engineering in particular.** Unfortunately the Engineering Directorate was slated for a 9 percent decrease in funding in the FY 2018 budget request, as compared to FY 2016 actual funding, with requested funding falling from $916 million in FY 2016 to $833 million requested for FY 2018.[32] A key reason why this matters is because while the United States has long led the world in science-based innovation, U.S. federal R&D dollars for basic science generate knowledge that is essentially a non-rival, non-appropriable public good that can be quickly picked up and leveraged by foreign competitors. This means that to successfully compete globally, the United States needs to become much more of an engineering-based economy that embraces a real engineering culture. And in terms of sciences, that means less relative prioritization of subjects like geosciences and social sciences, which is important but mainly about knowledge creation, in contrast to engineering, which can produce appropriable and sustainable gains for the U.S. economy. In other words, the overall budget of the NSF should increase, but a significant share of any increases should go to disciplines that can support U.S. manufacturing, especially engineering and computer science.

The administration should establish at least five more STARnet-like programs. STARnet is a joint program operated by DARPA and the U.S semiconductor industry that funds early-stage research at leading U.S. research universities. STARnet coalesces a large, multi-university research community to look beyond current evolutionary directions to make discoveries that drive technology innovation beyond what can be imagined for semiconductor electronics today.[33]

A good first step in this regard is DARPA’s 2018 launch of the Joint University Microelectronics Program (JUMP). JUMP will consist of a half-dozen university-based research centers, each dedicated to a different technology theme and collectively supporting fundamental microelectronics research with a goal of catalyzing innovations enhancing the performance, efficiency, and overall capabilities of broad classes of electronics systems for both commercial and military applications. DARPA expects funding for the five-year effort to exceed $150 million, with DARPA providing 40 percent of that funding and consortium partners collectively contributing 60 percent.[34]

Finally, public-private partnerships such as America's network of 14 Institutes of Manufacturing Innovation (IMIs) that comprise Manufacturing USA can play a pivotal role in ensuring America's continued leadership in advanced manufacturing product and process technologies. Deloitte's January 2017 evaluation of the first eight Manufacturing USA institutes concluded that they:

- help spur R&D innovation and commercialization;
- prepare the 21st century workforce;
- encourage mutually beneficial collaboration to catalyze R&D investment;
- solve collective action problems;
- enable members to tap into critically valuable and synergistic stockpiles of intellectual property; and
- provide access to shared assets.[35]

All of this enables innovation to occur more efficiently. For instance, DOE's Manufacturing USA institutes have the potential to accelerate technological progress toward important national goals. These goals include economic competitiveness, high-quality jobs, national security, and environmental protection. If the Institutes are successful, U.S.-based manufacturers will become more productive, grow more quickly, and export more successfully than they would have in the Institutes' absence. Manufacturing workers will be better-trained and more capable of contributing to cutting-edge production. The defense industrial base will become more self-sufficient and flexible. Energy and material waste, and criteria and carbon pollution per unit of physical production, will decline. Properly managed, public investment in the Institutes will induce private investment and actions that "real-world" markets would not.

Barring obvious misconduct or failure, which we have not observed, **the federal government should uphold its end of the bargain by continuing to invest in these nascent organizations that comprise Manufacturing USA through at least the initial five-year start-up period.** Strategic patience is appropriate for an institutional innovation of this magnitude and with such a long time horizon. U.S. manufacturing and energy policy should "lean into the wind" against short-termism driven by equity markets.

Accordingly, **the administration and Congress should provide federal support for core institutional funding of the Manufacturing USA institutes on a permanent basis**. All participants in this program recognize that a full transition to non-programmatic funding within five years will be extremely challenging; even seven years will be a stretch in most cases. Comparable programs in other countries, such as Germany's Fraunhofer Institutes, receive ongoing public funding. Federal support at an ultimate level of no more than 20 to 25 percent of an Institute's budget would provide flexibility to Institute managers and confidence to industry members, while limiting the influence of the largest industry members, including foreignheadquartered firms, that might otherwise dominate an Institute's agenda. It would also maintain incentives for Institutes to seek industry members, ensuring that they remain industry-led.

3. What innovative tools, platforms, and technologies are needed for advances in manufacturing? Of those that already exist, what are the barriers to their adoption?

America's manufacturing supply chains are sometimes hamstrung by the fact SMMs lag in applying the latest technologies or production processes.[36] This is particularly the case when it comes to SMMs' adoption of digital technologies such as high-performance computing (HPC)-empowered modeling and simulation (M&S) or computer-aided design (CAD) and computer-aided engineering (CAE) software, 3-D printing, or the Industrial Internet of Things (IIoT). For instance, a June 2017 survey of 250 U.S. SMMs conducted by Sikich found 77 percent reporting that they still had no plans to implement IIoT technologies.[37] (These manufacturers were also investing relatively little in R&D, with 78 percent of the surveyed manufacturers reporting investments of less than 5 percent of sales.)[38] The SMMs surveyed cited a lack of internal expertise and a lack of internal workforce skills to support the digital technologies as the primary reasons for their low rates of IIoT investment.[39]

Platforms such as the Digital Manufacturing Commons (DMC) being developed by the Digital Manufacturing Design and Innovation Institute (DMDII) in Chicago, which is as a free, open-source software project to develop a collaboration and engineering platform that will serve as an online gateway for digital manufacturing, can help democratize SMMs' access to these types of digital production systems.[40] Akin to an "app store for manufacturing," the DMC provides SMMs access to a digital services marketplace, including software development kits, essentially equipping SMMs with HPC-powered CAD, CAE, and other advanced modeling and simulation tools they need to address technical design challenges.[41] In most cases, SMMs would be unable to afford either the needed sophisticated IT hardware or software, so this approach democratizes access to advanced computing and computational systems for SMMs.

4. How can such Federal agencies and centers develop and strengthen all levels of manufacturing education and training programs to ensure an adequate, well-trained U.S. workforce for the new advanced manufacturing jobs of the future?

This is indeed a serious challenge. According to Deloitte and The Manufacturing Institute's report "The Skills Gap in U.S. Manufacturing 2015 and Beyond," 70 percent of manufacturing company executives "report that their current workers do not have adequate technology and computer skills; over two-thirds indicate that they lack adequate problem-solving skills; and 60 percent indicate that they lack sufficient math skills. Most troublingly, over two-thirds indicate that they lack basic technical training."[42]

As noted previously, an expanded Manufacturing Engineering Education Grant program can play an important role in revamping university engineering programs toward curriculum and experiences better suited to producing graduates that will be better equipped with skills and competencies demanded by industry when they graduate.

Approximately 75 percent of college students would prefer an interdisciplinary education, and such training is also needed to improve workforce skills.[43] In particular, better incorporation of educational experiences in design, innovation, entrepreneurship, and industrial research into graduate science and engineering programs is needed. NSF offered a program that tackled this challenge as part of the Integrative Graduate Education Research Training (IGERT) program, which in 2014 became the NSF Research Traineeship (NRT) program.[44] NRT's mission is to invest directly in the development of the science, technology, engineering, and mathematics (STEM) workforce, and in the improvement of the education of tomorrow's STEM workforce, thus providing a mechanism for developing a knowledge base about the implementation and impact of innovative graduate traineeship programs and graduate education policies.[45] Unfortunately, NSF's FY 2018 budget request for the program of $40.1 million represented a decrease of $15.9 million over FY 2016 funding levels.[46] **The administration should prioritize funding and expansion of the NRT program going forward.**

DOE has a well-developed apparatus for supporting graduate students and post-docs and, to a lesser extent, undergraduate students through research assistantships, traineeships, and the like. It has less experience in supporting or providing training programs for workers or prospective workers who have not graduated from college. Perhaps influenced by their sponsor, DOE's Manufacturing Institutes' educational programs emphasize engineering and research, rather than operations and maintenance activities performed by mid-skill workers. In technical areas in which innovations have yet to diffuse widely, such an emphasis may be inevitable. However, the Institutes should be encouraged to search for opportunities to provide training to mid-skill workers. The deepening engagement in Manufacturing USA of the Departments of Education and Labor, as called for by the 2017 Government Accounting Office (GAO) report, should aid in developing such programs. DOE's Institutes may also draw upon the Multi-Skilled Technician Core Competency Model that the Manufacturing USA workforce team has put together and work in partnership with NSF's Advanced Technical Education (ATE) program, which engages technicians in undergraduate programs preparing for the high-technology fields that drive America's economy. **The administration's should ask for funding for the ATE program of at least $80 million.**[47]

When it comes to smart manufacturing, DMDII has partnered with ManpowerGroup to develop a comprehensive taxonomy of emerging roles and skills in the digital manufacturing and design space. The report identifies 165 potential digital manufacturing and design roles, providing a comprehensive index of requisite skills and representative tasks pertaining to each role, and offers 20 success profiles for representative roles.[48] It's a very impressive report and taxonomy that should be widely diffused across America's manufacturing base.

5. How can such Federal agencies and centers develop and strengthen all levels of manufacturing education and training programs to ensure an adequate, well-trained U.S. workforce for the new advanced manufacturing jobs of the future?

America's Hollings Manufacturing Extension Partnership (MEP), which operates out of the National Institute of Standards and Technology (NIST) at the U.S. Department of Commerce, works with small and mid-sized U.S. manufacturers to help them create and retain jobs, increase profits, and save time and money.[49] MEP is a public-private partnership with centers in all 50 states (and Puerto Rico) dedicated to increasing the technical and innovation capacity of America's SMMs.[50]

MEP delivers a significant return on investment for U.S. taxpayers.[51] In fact, estimates find that for every one dollar of federal investment, the MEP generates $19 in new sales growth and $21 in new client investment. This translates into $2.2 billion in new sales annually. And for every $1,978 of federal investment, MEP creates or retains one manufacturing job.[52] In 2016, the MEP National Network connected with 25,445 manufacturers, leading to $9.3 billion in sales, $1.4 billion in cost savings, $3.5 billion in new client investments, and helping to create and retain more than 86,602 U.S. manufacturing jobs.[53] Since 1988, MEP has worked with 94,033 manufacturers, leading to $98.7 billion in sales and $17.1 billion in cost savings, and helping to create or retain more than 884,596 jobs.[54]

MEP has achieved these successes despite the fact that the United States substantially underinvests in MEP relative to both its own historical norms and compared to investments made by competitor nations. MEP's budget in 2016, $130 million, was scarcely more than its 1998 budget of $113.5 million, meaning that, as a share of GDP, the United States invested 1.58 times more in supporting its SMMs in 1998 than it did in 2016.[55] Moreover, as a share of GDP, Japan invests 30 times more in its Kohsetsushi centers than the United States invests in its MEP, Germany invests approximately 20 times as much, and Canada has invested almost 10 times as much in its Industrial Research Assistance Program (IRAP).[56]

Put simply, MEP represents one of the most effective programs operating within the U.S. government. **It is imperative that future budget proposals from the Trump administration not zero out funding for this agency but rather fund it at least in-line with America's own historical norms, which would mean closer to $200 million in annual funding.** Historically, MEP has been organized by state (at least one in each of the 50), but MEP should also continue to evaluate how it can work with SMMs more effectively across both state lines and supply chains. Because supply chains cross state boundaries there needs to be more cross-state, sector-based MEPs (e.g., autos in the U.S. Midwest and South). In other words, MEP should take on more of a supply-chain and sector-based focus. MEP should also expand its supply chain optimization (SCO) initiative, designed to help manufacturers build dynamic supply chains by developing a long-term strategy, increasing visibility throughout multiple supplier tiers, identifying and mitigating risk, identifying enterprise resource planning (ERP) systems that are compatible across supply chain tiers as well as appropriate and affordable for SMMs, and understanding total cost of ownership (TCO) and other best practices that encourage strategic partnerships throughout the supply chain.[57]

A key step that appears to be fully implemented now is MEP's program of embedding staff within each Institute of Manufacturing Innovation in order to facilitate the diffusion of technologies and processes being developed at the Institutes out to America's broader SMM supplier base. This represents an important step toward expanding outreach to existing SMMs, which matters because many SMMs possess great potential to adopt the innovations being developed at the Institutes. Yet the barriers to reach them remain high. Thus, the program should be sustained, and the Institutes encouraged to build around it. There may be additional opportunities for synergies with existing small business programs, such as the Small Business Innovation Research (SBIR) program and the national labs' small business voucher pilot program. Traditionally, states have provided vouchers for small businesses to redeem at universities or local research institutes in order to enable knowledge transfers between startups and research institutes, support sectoral innovation in manufacturing, support innovation management and advisory services, speed commercialization of startup ideas, and focus research institutions on the commercial applications of their research. **The administration should advocate for a small business innovation voucher program redeemable with the Institutes of Manufacturing Innovation, ideally with the federal government matching investments states would make dollar-for-dollar.**

6. How would you assess the state of the following factors and how they impact innovation and competitiveness for United States advanced manufacturing?

(a) technology transfer and commercialization activities;

This is absolutely vital. The situation is improving, but will and should always be in a constant state of refinement and improvement. There are some positive steps: for instance, the Lab-Embedded Entrepreneurship Program (LEEP) which seeks to "spin-in" entrepreneurs to the U.S. national labs. There are currently three LEEPs—Cyclotron Road at Lawrence Berkeley, the Chain Reaction Innovations (CRI) program at Argonne National Laboratory, and the Innovation Crossroads program at Oak Ridge National Laboratory (ORNL)—with a fourth to be announced shortly.[58] The LEEPs are helping to develop a new technology transition model of "inside-out" innovation, getting the labs to transition from a historical focus only on moving their own technologies outside the lab, to a new "outside-in" model that gives entrepreneurs access to the advanced technology, equipment, and know-how that the national labs possess.

Another positive innovation has been DOE Energy Efficiency and Renewable Energy's (EERE's) Small Business Voucher Pilot (SBV), which has provided vouchers to 33 small business across 20 states working with nine national labs. One example has been that Tennessee and the Oak Ridge National Laboratory (ORNL) collaborated to launch "RevV," a $2.5 million manufacturing innovation program. The pilot program offers vouchers allowing Tennessee manufacturers access to the world-class researchers and facilities available at ORNL. **ITIF has called on Congress to extend such vouchers across the entire federal lab system by authorizing $50 million that would be state-matched.**

NSF's I-Corps program continues to grow in terms of Teams, Nodes, and Sites across the country. It has recently been complemented by Energy I-Corps, a $2.3 million pilot program designed to teach "entrepreneurial scientists" at the national laboratories lean startup and customer discovery methodologies. As Johanna Wolfson, the Former Technology-to-Market Director at DOE EERE, notes, "Energy I-Corps is not just a success if the scientist creates a spin-out of the lab. It's a success as well if the researchers go back to their lab bench and think differently about their work moving forward."[59] **NSF I-Corps and DOE's Energy I-Corps programs should continue to be expanded.**

However, as ITIF writes in "Localizing the Economic Impact of Research and Development: Policy Proposals for the Trump Administration and Congress," there are many more steps that could be taken by the administration and/or Congress to further improve America's technology transfer and commercialization ecosystem. These include:

- **Increasing the importance of commercialization activities at federal labs/research institutes;**
- **Allocating a share of federal funding to promote technology transfer and commercialization;**
- **Developing a proof-of-concept, or "Phase Zero," individual and institutional grant award program within major federal research agencies;**
- **Supporting university-based technology accelerators/incubators to commercialize faculty and student research;**
- **Funding pilot programs supporting experimental approaches to technology transfer and commercialization;**
- **Increasing the allocation of federal agencies' SBIR project budgets to commercialization activities**.[60]

(b) the adequacy of the national security industrial base;

Overall, ITIF would describe the situation as moderate but weakening, and as of concern for some time. For instance, Yudken's 2011 report, "Manufacturing Insecurity: America's Manufacturing Crisis and the Erosion of the U.S. Defense Industrial Base," identified a number of technologies in which domestic sourcing is endangered, including propellant chemicals, space-qualified electronics, power sources for space and military applications (especially batteries and photovoltaics), specialty metals, hard disk drives, and flat panel displays (LCDs).[61] Similarly, Michael Webber, an engineering professor at the University of Texas, has studied the economic health of 16 industrial sectors within the manufacturing support base of the U.S. defense industrial system that "have a direct bearing on innovation and production of novel mechanical products and systems," and finds that, since 2001, 13 of those 16 industries have shown "significant signs of erosion."[62] As Heritage's James Carfano writes, "The U.S. defense base is on the verge of a crisis—losing the design engineering and industrial capacity to affordably produce the cutting-edge military systems that once gave the American military an unassailable advantage."[63]

Such concerns were amplified by a May 2012 Senate Committee on Armed Services report on the extent to which counterfeit electronic parts had infiltrated the U.S. defense supply chain. The report, which looked at just one part of the defense supply chain from 2009 to 2010, documented 1,800 cases of suspected counterfeit electronic parts being deployed on a wide range of weapons systems, including anti-submarine aircraft and helicopters, cargo planes, and missile defense systems such as the Terminal High-Altitude Missile Defense (THAAD) system.[64] And alarmingly, the reality is that, "the United States does not have a comprehensive program to certify that integrated circuits (ICs) going into U.S. weapons systems do not contain malicious circuits."[65] In response, DARPA recently announced the TRUST in Integrated Circuits program to develop technologies that will ensure the trust of ICs used in military systems, but designed and fabricated under untrusted conditions.

In summary, the United States must do much more to support the adequacy and vitality of its defense industrial base.

(c) the capabilities of the domestic manufacturing workforce;

America's manufacturing workforce has many strengths, but will be increasingly challenged to upskill and acquire digital skills as manufacturing activity becomes increasingly digitalized. For instance, a recent study by Accenture contends that as many as 80 percent of America's manufacturing workers lack at least some essential skills needed to take full advantage of the potential of smart manufacturing.[66] Moreover, the number of open manufacturing jobs has increased virtually every year since 2009, with the U.S. Department of Labor finding that between June 2015 and June 2016 there was an average of two unemployed manufacturing workers for each open position.[67] Lacking "upskilling" in the manufacturing sector partly explains the skills and job mismatch.[68]

Policymakers should continue to make use of digital tools to help train America's manufacturing workforce with the digital (and other skills) they'll need to compete in an increasingly competitive global manufacturing economy.[69] For instance, Tooling U-SME, a web-based, cloud-delivered, massively open online course (MOOC) provides over 500 online classes related to manufacturing technology, breaking down the training into nine functional areas and 60 competency models to identify gaps, define requirements, and provide specific guidance for development.[70] Tooling U-SME's "Accelerate Methodology" provides a comprehensive, structured, enterprise-specific approach that helps manufacturers and their workers acquire needed skills. Similarly, the Digital Manufacturing and Design Innovation Institute has developed a Coursera-hosted MOOC that's teaching essential skills related to digital manufacturing and design technologies.[71]

(d) export opportunities and trade policies;

ITIF's report "Fifty Ways to Leave Your Competitiveness Woes Behind: A National Traded Sector Competitiveness Strategy" provides a number of policy recommendations to bolster U.S. manufacturers' export opportunities and to strengthen U.S. trade policy.[72] A comprehensive description of the recommendations and their rationale may be found in that report, but they include:

- **Better supporting and aligning programs to boost U.S. exports;**
- **Promoting reshoring;**
- **Creating global knowledge investment zones to attract foreign direct investment;**
- **Providing forgivable loans to companies supporting repatriated jobs to distressed/rural areas;**
- **Updating the charter of the Committee on Foreign Investment in the United States (CFIUS) to address the realities of modern-age state capitalism;**
- **Reviewing export control policies that inhibit U.S. exports;**
- **Developing a national trade strategy and increasing funding for U.S. trade policymaking and enforcement agencies;**

- **Excluding mercantilist nations from participation in the Generalized System of Preferences (GSP), which eliminates duties on thousands of products from 120 designated nations and territories;**
- **Improving existing trade agreements such as NAFTA or KORUS and forging new or joining existing high-standard regional trade agreements such as the Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP).**

In particular, one focus of policy should be impressing upon U.S. manufacturers that smart-manufacturing techniques will increasingly enable competitive manufacturing in high-cost environments.[73] For example, professor Suzanne de Treville of the University of Lausanne has developed supply-chain analytics tools that help companies quantify and price the advantages they have in manufacturing locally, making it easier to show that the apparent cost reduction offered by a competitor in a low-wage country might not be as compelling as it seems. By applying quantitative finance tools to demand dynamics, Treville's freely available Cost-Differential Frontier (CDF) price calculator allows manufacturers to price the increase in exposure to demand volatility that comes from increases in lead time.[74] Many companies applying the tool find that the supply-chain mismatch costs arising from increased demand-volatility exposure are frequently greater than the cost reduction offered by an offshore supplier, and that going offshore is often not a bargain. Combining this analysis with quantifying the impact of possible demand peaks also allows companies to rethink cost allocations depending on time sensitivity. In total, the tool helps manufacturers to understand volatility in order to manufacture closer to their markets, and more profitably (and without requiring subsidies).

(e) financing, investment, and taxation policies and practices;

This remains a significant problem for the U.S. economy. U.S. manufacturers are still too pressured by Wall Street for short-term returns. For instance, as the Business Roundtable notes, "The obsession with short-term results by investors, asset management firms, and corporate managers collectively leads to the unintended consequences of destroying long-term value, decreasing market efficiency, reducing investment returns, and impeding efforts to strengthen corporate governance."[75] In fact, in a 2004 survey of more than 400 U.S. executives, 80 percent indicated that they would decrease discretionary spending on areas such as R&D, advertising, maintenance, and hiring in order to meet short-term earnings targets and more than 50 percent said they would delay new projects, even if it meant sacrifices in value creation.[76] **To address this, Congress or the administration should establish a national commission to identify legislative and regulatory steps that would encourage companies to invest more for the long term.** For example, such a commission might consider a proposal from the Institute of Corporate Directors to replace quarterly financial reports with less frequent updates, such as half-yearly results.[77] **At the same time the Trump administration should direct the Administrator of the SBA to identify steps to ensure that at least one-third of all SBA 7A loans are made to manufacturers.** Right now the share is only 7.5 percent.

(f) federal regulations;

The Trump administration has made significant progress in regulatory review, although it should remember that there are some cases in which enlightened regulation can be competition- or innovation-enhancing. Yet more could be done. For instance, the Office of Information and Regulatory Affairs (OIRA) within the Office of Management and Budget (OMB) could create an Office of Innovation Review (OIR) that would have the specific mission of being the "innovation champion" within administration regulatory review processes.[78] OIR would have authority to push agencies to either affirmatively promote innovation or to achieve a particular regulatory objective in a manner least damaging to innovation.

Another approach would be to require OIRA to incorporate a "competitiveness screen" in its review of federal regulations. Regulatory agencies seeking to impose regulations that affect traded sectors in non-trivial ways should be required to have these regulations undergo a review by OMB's OIRA for their first-order competitiveness impact. For example, environmental regulations that might directly affect how semiconductors are produced would be required to undergo review. Given the limited amount of time and attention available for regulatory review, the highest priority should be placed on reviewing those regulations that directly impact traded sectors.[79] Increasing industry's participation in federal rule-making processes would help reduce the complexity of regulatory compliance, emphasize cost/benefit analysis, and restrict the executive branch's impulse to "legislate by regulation."[80]

(g) emerging technologies and markets;

With regard to emerging technologies, the **administration should repurpose the National Robotics Initiative (NRI) away from "cobots" to robots that actually replace workers**. NSF's new NRI-2.0 program builds upon the original National Robotics Initiative program to support fundamental research in the United States that will accelerate the development and use of collaborative robots (co-robots) that work beside or cooperatively with people.[81] The Initiative plans a $50 million research budget to develop such co-robots as part of the Advanced Manufacturing Partnership Program. While cobots will have their place in some settings (like healthcare), the program is too cowed by those who believe robots will take away massive amounts of jobs, when what U.S. manufacturers really need are the most-productive and capable automation systems possible, including robotics, because it's by being the most efficient and innovative that our manufacturers will remain the most globally competitive.[82]

(h) advanced manufacturing research and development undertaken by competing nations; and

ITIF will release in coming weeks a new report that assesses ten countries' recent and new policies and programs supporting SMMs as well as their Industry 4.0 or "smart manufacturing" initiatives. This report will much more comprehensively address this question.

Yet it's also worth noting that the Manufacturing USA initiative sparked an international response, even in nations that were already investing proportionally more in their manufacturing sectors than the United States. Germany, whose €1.9 billion network of Fraunhofer Institutes helped to inspire the Manufacturing USA network, had already launched a national strategic initiative—Industrie 4.0—to drive forward digital manufacturing and the Internet of Things. The United Kingdom established its High-Value Manufacturing Catapult program, a network of seven public-private centers aimed at accelerating innovation in growth sectors. South Korea announced a Manufacturing Industry Innovation 3.0 strategy, which focuses on R&D projects in areas to accelerate Korean manufacturers' use of the Internet of Things, smart sensors, and big data. China's "Made in China 2025" strategy has called on China's Ministry of Industry and Information Technology (MIIT) to establish 40 Manufacturing Innovation Centers (almost directly modeled on America's Manufacturing USA approach) utilizing public and private funds and focused on creating domestic technologies. China has launched two such Centers, one focused on additive manufacturing and one on advanced batteries that has received a commitment of $400 million in funding through 2020. Not coincidentally, the first Manufacturing Innovation Center China launched directly mirrored AmericaMakes and its focus on additive manufacturing.

(i) the capabilities of the manufacturing workforce of competing nations.

The forthcoming ITIF report will address in greater detail.

7. Is there any additional information related to advanced manufacturing in the United Stated, not requested above, that you believe OSTP should consider?

It should be recognized that energy plays an important role in manufacturing competitiveness. Low energy costs have been an important driver of "reshoring" manufacturing to the United States over the past decade. Cheap natural gas from shale made available by hydraulic fracturing techniques has given the nation a particular advantage in energy-intensive sectors, such as petrochemicals. Although the sector overall has been producing more goods with less energy over time, it still wastes about one-quarter of the energy it uses, and the figure is much higher in energy-intensive sectors. Rapid innovation to reduce such waste could create opportunities to disrupt such sectors in the future, as Germany, among other nations, has recognized.[83]

The energy sector is also a major consumer of manufactured goods. The shale gas boom was a critical factor in pulling manufacturing out of the recession through its demand for pipes, drilling equipment, and other supplies. In 2015, for instance, nearly $3 billion flowed to the manufacturing sector from pipeline construction alone, supporting around 22,000 jobs. Yet, competition to supply the energy sector is fierce. The rapid growth of emerging energy technologies, such as wind turbines and batteries, has intensified this contest, as nations perceive the opportunity to seize control over brand new supply chains. Innovative products and processes are critical to success in this race. China, for instance, recently set the goal of becoming a "technologically independent energy storage superpower."[84]

The close linkages between industrial energy use, manufacturing for the energy industry, and environmental quality are obvious. Industry consumes about one-quarter of the nation's primary energy supply, depending particularly on natural gas, petroleum, and electricity. More efficient use of these inputs would limit local air pollution near factories and power plants as well as environmental impacts upstream due to drilling, mining, pipelines, and power lines. The industrial sector is also responsible for about 22 percent of U.S. carbon emissions.[85] Reducing these emissions, especially for process heat, poses some of the most difficult technical challenges for achieving a transition to low-carbon energy resources.[86]

At the same time, the low-carbon energy transition is creating huge opportunities for manufacturers who supply the energy industry. Global investments worth an estimated $333.5 billion in 2017 for clean energy goods ranging from solar panels and windmills to geothermal and biomass, not to mention upgraded systems for controlling energy flows and transporting energy carriers, are at stake.[87] Innovation will be one of the United States' key competitive advantages as these markets develop in the coming decades.

The private sector is ultimately responsible for implementing innovations at the nexus of energy and manufacturing, and it generates and commercializes many such innovations as well. Market failures, however, lead to many gaps in the private-sector response to the innovation imperative. These failures extend beyond obvious externalities that justify an active role for the federal government, such as national security and environmental protection, to include the economic and workforce dimensions of the imperative, which also call for a public response.

At the regional level, for instance, markets may fail to adequately incentivize the creation of shared infrastructures that would strengthen industrial clusters. Regional clusters of like-minded firms were observed by the pioneering economist Alfred Marshall in the 19th century, and they remain common today, especially in manufacturing. Recent research has shown that the collective pool of industry-specific knowledge in a region is a key cause of clustering. Yet in many U.S. regions, this "industrial commons" (as management scholars Gary Pisano and Willie Shih have termed this pool of knowledge and the means for generating it) has been decimated. Often, firms that benefited from the industrial commons were unaware of their dependence on it or were unable to organize effectively to strengthen it before it disappeared.[88]

Finally, a major contributing factor to this process of regional hollowing out has been government-subsidized international competition. As noted previously, although the United States might prefer for world trade to occur in a free market, it does not always do so. Many countries have targeted manufacturing for special treatment because of its economic development and export potential. For instance, the big decline in U.S. manufacturing employment during the 2000s was caused in part by the "China shock" that followed that country's accession to the World Trade Organization. Although low labor costs and other market factors are part of the explanation for this shift of manufacturing activity, China's mercantilist policies, which ITIF has documented extensively, played a significant part as well.[89] The hollowing out of America's regional industrial ecosystems is thus yet another reason that validates a national manufacturing strategy.

In conclusion, the United States needs a robust National Strategic Plan for Advanced Manufacturing. ITIF commends OSTP and the administration for its commitment to develop one.

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