Assessing and Strengthening the Manufacturing and Defense Industrial Base and Supply Chain Resiliency of the United States

Report to President Donald J. Trump
by the Interagency Task Force in Fulfillment of
Executive Order 13806

September 2018

Contents

I. Executive Summary

Requirement

On July 21, 2017, President Donald J. Trump signed Executive Order (EO) 13806 on Assessing and Strengthening the Manufacturing and Defense Industrial Base and Supply Chain Resiliency of the United States. The EO directs the Secretary of Defense to conduct a whole-of-government effort to assess risk, identify impacts, and propose recommendations in support of a healthy manufacturing and defense industrial base – a critical aspect of economic and national security.[1] The EO 13806 effort was initiated by the White House Office of Trade & Manufacturing Policy led by the Department of Defense's Office of Industrial Policy in coordination with the Departments of Commerce, Labor, Energy, and Homeland Security, and in consultation with the Department of the Interior, the Department of Health and Human Services, the Director of the Office of Management and Budget, the Director of National Intelligence, the Assistant to the President for National Security Affairs, the Assistant to the President for Economic Policy, and the Assistant to the President for Trade & Manufacturing Policy.

America's manufacturing and defense industrial base ("the industrial base") supports economic prosperity and global competitiveness, and arms the military with capabilities to defend the

nation. Currently, the industrial base faces an unprecedented set of challenges: sequestration and uncertainty of government spending; the decline of critical markets and suppliers; unintended consequences of U.S. Government acquisition behavior; aggressive industrial policies of competitor nations; and the loss of vital skills in the domestic workforce. Combined, these challenges – or macro forces – erode the capabilities of the manufacturing and defense industrial base and threaten the Department of Defense's (DoD) ability to be ready for the "fight tonight," and to retool for great power competition. The following report explains the macro forces impacting the industrial base, identifies primary categories of risk, illustrates impacts within sectors, and provides recommendations for mitigation.

Methodology

The EO 13806 assessment evaluated risk based on current and planned operating priorities as of late 2017/early 2018. An Interagency Task Force, led by DoD, created sixteen working groups with over 300 subject matter experts from across the federal government. Nine working groups focused on traditional sectors; seven working groups assessed enabling, cross-cutting capabilities (Figure 1).

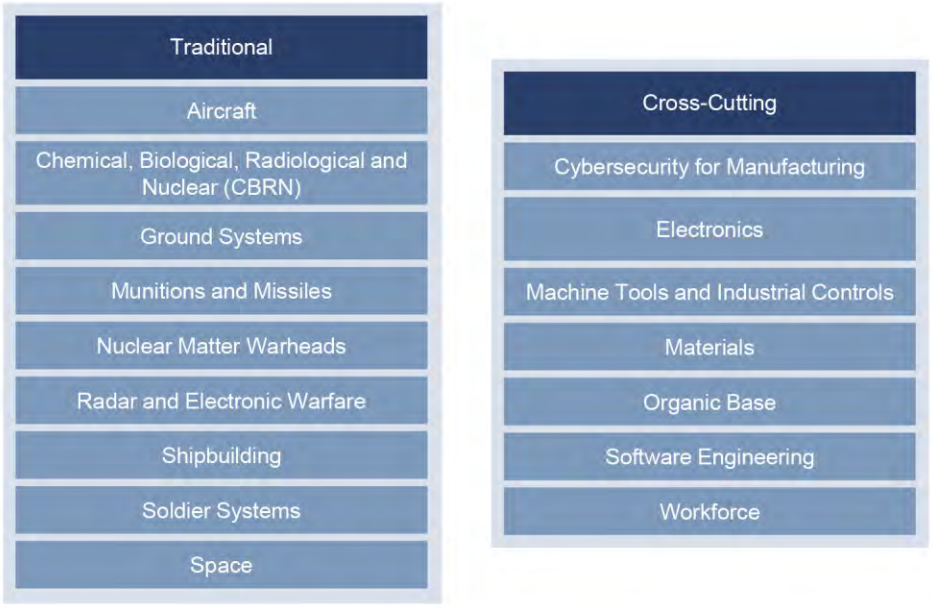


Figure 1: List of Traditional and Cross-Cutting Sectors

These macro forces collectively represent the root causes of ten risk archetypes distributed throughout the industrial base. The working groups identified discrete impacts within their sectors, many of which fall under more than one risk archetype, as illustrated in Figure 2.

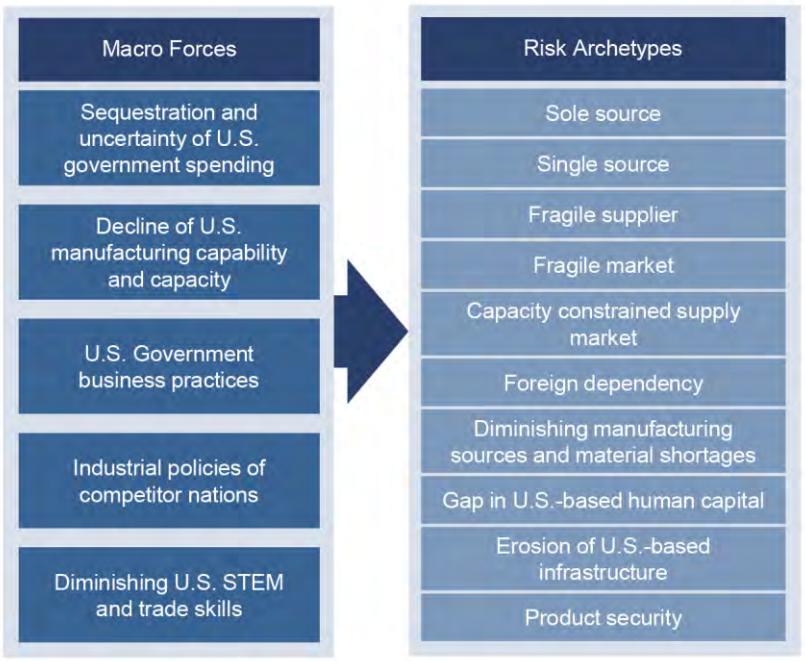


Figure 2: Macro Forces Map to Risk Archetypes

Findings

The risk framework used for the EO 13806 effort evolved from the working groups' assessments of their sectors. The assessment identified:

- Five macro forces shaping industrial base-wide trends and causing a deterioration in U.S. capabilities;
- Ten risk archetypes resulting from the macro forces, each of which contribute to insecurity in DoD's supply chain;
- Over 280 impacts across sectors, acutely affecting the vitality and resiliency of the industrial base.*

Major findings include:

- Macro forces have led to impacts primarily in the sub-tiers of the defense supply chain;
- A surprising level of foreign dependence on competitor nations exists;
- Workforce challenges face employers across all sectors; and
- Many sectors continue to move critical capabilities offshore in pursuit of competitive pricing and access to foreign markets.

* A classified spreadsheet provides a comprehensive list of impacts across risk archetypes for fifteen sectors; due to its proliferation across sectors, the software engineering working group assessed impacts across all sectors.

Recommendations

The DoD-led Interagency Task Force recognizes ongoing efforts to address the challenges identified in the EO 13806 assessment, including:

- Increased near-term DoD budget stability with the passage of the Bipartisan Budget Act of 2018, providing stable funding through Fiscal Year (FY) 2019
- Modernization of the Committee on Foreign Investment in the U.S. and investigations under Section 301 of the Trade Act of 1974 into Chinese intellectual property theft, to better combat Chinese industrial policies targeting American intellectual property
- Updates to the Conventional Arms Transfer policy and unmanned aerial systems export policy to increase U.S. industrial base competitiveness and strengthen international alliances
- Reorganization of the former Office of the Under Secretary of Defense for Acquisition, Technology and Logistics, the work of the "Section 809 panel," and development of the adaptive acquisition framework all aim to streamline and improve defense acquisition processes
- Restructuring the Defense Acquisition University to create a workforce education and training resource to foster increased agility in acquisition personnel
- Response to Section 1071(a) of the National Defense Authorization Act for FY2018 which requires establishing a process for enhancing the ability to analyze, assess, and monitor vulnerabilities of the industrial base
- Creation of a National Advanced Manufacturing Strategy by the White House Office of Science and Technology Policy, focused on opportunities in advanced manufacturing
- Department of Labor's chairing of a Task Force on Apprenticeship Expansion to identify strategies and proposals to promote apprenticeships, particularly in industries where they are insufficient
- DoD's program for Microelectronics Innovation for National Security and Economic Competitiveness to increase domestic capabilities and enhance technology adoption
- DoD cross-functional team for maintaining technology advantage
- Implementation of a risk-based methodology for oversight of contractors in the National Industrial Security Program, founded on risk management framework principles to assess and counter threats to critical technologies and priority assets

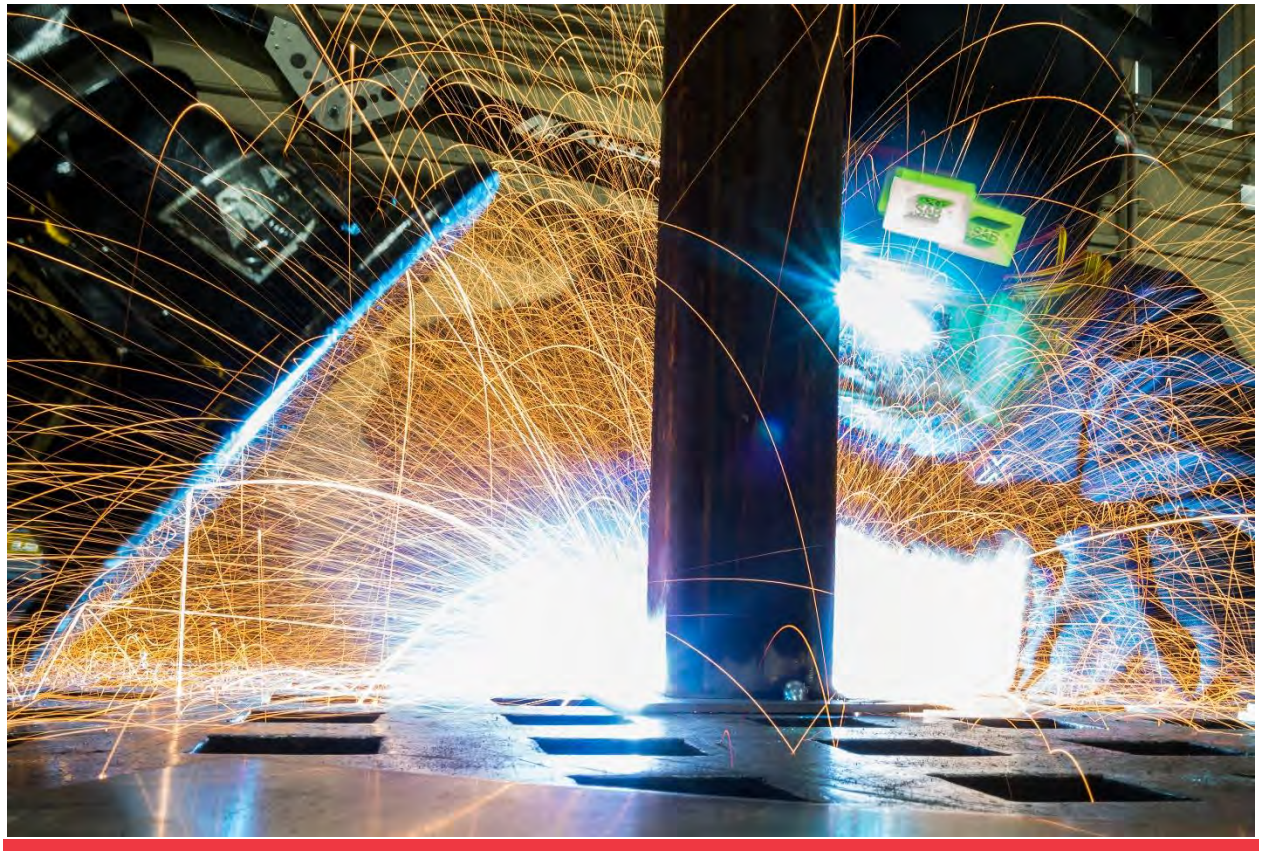
In addition to the ongoing efforts outlined above, the DoD-led Interagency Task Force created a set of recommendations aligned to four levers: investment, policy, regulation, and legislation. The recommendations are organized by the Secretary, with DoD's recommendations provided in a classified Action Plan. In summary, the recommendations propose:

- Create an industrial policy in support of national security efforts, as outlined in the National Defense Strategy, to inform current and future acquisition practices

- Expanding direct investment in the lower tier of the industrial base through DoD's Defense Production Act Title III, Manufacturing Technology, and Industrial Base Analysis and Sustainment programs to address critical bottlenecks, support fragile suppliers, and mitigate single points-of-failure
- Diversifying away from complete dependency on sources of supply in politically unstable countries who may cut off U.S. access; diversification strategies may include reengineering, expanded use of the National Defense Stockpile program, or qualification of new suppliers
- Working with allies and partners on joint industrial base challenges through the National Technology Industrial Base and similar structures
- Modernizing the organic industrial base to ensure its readiness to sustain fleets and meet contingency surge requirements
- Accelerating workforce development efforts to grow domestic science, technology, engineering, mathematics (STEM), and critical trade skills
- Reducing the personnel security clearance backlog through more efficient processes
- Further enhancing efforts to explore next generation technology for future threats

A challenge this large demands a multifaceted approach. Therefore, the classified Action Plan also includes direction for DoD to conduct a comprehensive study on the industrial base requirements needed to support force modernization efforts, specifically focused on the technologies necessary to win the future fight.

This page intentionally blank.



II. Introduction

"It would, also, be a material aid to manufactures of this nature, as well as a mean of public security, if provision should be made for an annual purchase of military weapons, of home manufacture, to a certain determinate extent, in order to the formation of arsenals; and to replace, from time to time, such as should be drawn for use, so as always to have in store the quantity of each kind which should be deemed a competent supply."

— Secretary of the Treasury Alexander Hamilton,
Report on the Subject of Manufactures (1791)

To provide for our national security, America's manufacturing and defense industrial base must be secure, robust, resilient, and ready. To ensure taxpayer dollars are frugally and wisely spent, the defense industrial base must be cost-effective, cost-efficient, highly productive, and not unduly subsidized. In the event of contingencies, the industrial base must possess sufficient surge capabilities. Above all, America's manufacturing and defense industrial base must support economic prosperity, be globally competitive, and have the capabilities and capacity to

rapidly innovate and arm our military with the lethality and dominance necessary to prevail in any conflict. As President Trump stated in the 2017 National Security Strategy:

> *"A healthy defense industrial base is a critical element of U.S. power and the National Security Innovation Base.[†] The ability of the military to surge in response to an emergency depends on our Nation's ability to produce needed parts and systems, healthy and secure supply chains, and a skilled U.S. workforce."*[2]

All facets of the manufacturing and defense industrial base are currently under threat, at a time when strategic competitors and revisionist powers appear to be growing in strength and capability. As stated in the National Defense Strategy:

> *"The central challenge to U.S. prosperity and security is the reemergence of long-term, strategic competition by what the National Security Strategy classifies as revisionist powers. It is increasingly clear that China and Russia want to shape a world consistent with their authoritarian model – gaining veto authority over other nations' economic, diplomatic, and security decisions."*[3]

At least five macro forces cause the risks now threatening America's industrial base. From FY2012 through FY2017, sequestration led to lower defense spending relative to levels projected before sequestration was put in place. Antiquated and counter-productive procurement practices induced contracting delays, deterred market entry, discouraged innovation, and increased costs to suppliers. Decreases in key production capabilities and declines in manufacturing employment, relative to the last time the U.S. faced a great power competition, left key weaknesses that threaten the nation's manufacturing capabilities. The industrial policies of foreign competitors have diminished American manufacturing's global competitiveness – sometimes as collateral damage of globalization, but also due to specific targeting by great powers like China. Finally, emerging gaps in our skilled workforce, both in terms of STEM as well as core trade skills (e.g., welding, computer numeric control operation, etc.) pose increasing risk to industrial base capabilities.[4]

Arising from these macro forces is a set of ten risk archetypes with discrete impacts on America's manufacturing and defense industrial base. These include the rise of single and sole source suppliers which create individual points of failure within the industrial base, as well as fragile suppliers near bankruptcy and entire industries near domestic extinction. Due to erosion that has already occurred, some manufacturing capabilities can only be procured from foreign suppliers, many of which are not domiciled in allied and partner nations. The concomitant gaps

[†] The National Security Strategy defines the National Security Innovation Base as the American network of knowledge, capabilities, and people—including academia, National Laboratories, and the private sector—that turns ideas into innovations, transforms discoveries into successful commercial products and companies, and protects and enhances the American way of life.

in U.S.-based human capital and erosion of domestic infrastructure further exacerbates the challenge. Ultimately, these negative impacts have the potential to result in limited capabilities, insecurity of supply, lack of R&D, program delays, and an inability to surge in times of crisis.

In recognition of these emerging threats, risks, and impacts, EO 13806,[5] initiated by the White House Office of Trade & Manufacturing Policy and signed by President Trump on July 21, 2017, directed the Secretary of Defense to conduct a whole-of-government assessment of America's manufacturing and defense industrial base. The Secretary of Defense was further directed to provide the President with a set of specific actions to address any identified risks and gaps. This report fulfills these directives.

Part III outlines the methodology used in this assessment of the industrial base. Part IV briefly describes America's manufacturing and defense industrial base. Part V describes five macro forces that collectively represent the root causes of the emerging threats to America's industrial base, driving risk at the market and firm level. Part VI explains each of the ten major risk archetypes identified by the DoD-led Interagency Task Force, with examples identified by the sector working groups. Part VII provides a blueprint for specific actions to begin mitigating risk and impacts within America's manufacturing and defense industrial base.

This page intentionally blank.

III. Methodology

To meet the goals of EO 13806, the White House Office of Trade and Manufacturing Policy and the DoD's Office of Industrial Policy established an Interagency Task Force and authorized a set of working groups.[‡] Multiple organizations within DoD as well as the Departments of Commerce, Education, Energy, Homeland Security, and Labor contributed resources to the 16 working groups. Each working group, led by a sector specialist, assembled teams of subject matter experts – over 300 people in total – who identified manufacturing and industrial base risks, outlined sector-specific impacts, and recommended actions for mitigation.

The DoD-led Interagency Task Force identified and assessed nine traditional and seven cross-cutting sectors of the manufacturing and defense industrial base, listed in Figure 3. Sectors – ranging from aircraft and missiles to workforce and materials – were selected based on current operational priorities.[6] Appendix Two provides sector definitions and case studies outlining

[‡] DoD's Office of Industrial Policy (formerly known as Manufacturing and Industrial Policy) provides Congress with an Annual Industrial Capabilities report, which supplied a strong basis upon which to determine the sectors of focus for the EO 13806 effort. The Annual Industrial Capabilities report identifies risks but does not make recommendations, a major distinction between the two efforts.

examples of risk and impacts in each sector. To appropriately scope the EO 13806 effort, the Interagency Task Force recommended evaluation of next generation technologies as part of a follow-on effort.

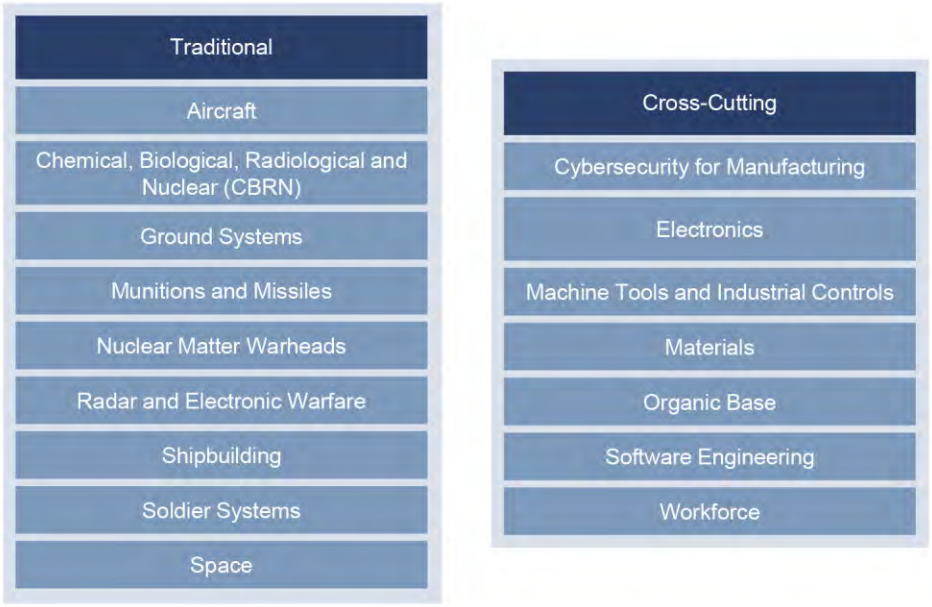


Figure 3: List of Traditional and Cross-Cutting (enabling) Sectors

To develop the manufacturing and defense industrial base assessment framework, the DoD-led Interagency Task Force tasked each working group to determine risks within their sectors based on their individual frameworks. After gathering and analyzing the disparate risks across the working groups, a pattern of macro forces and risk archetypes emerged, coalescing in a comprehensive risk framework (Figure 4) from which to address the health of the industrial base.

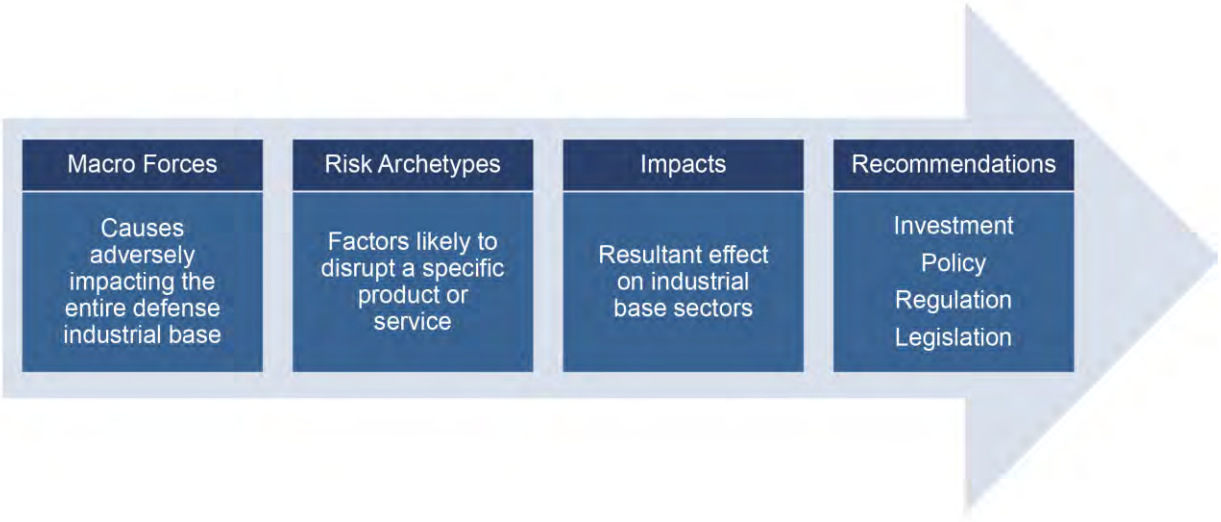


Figure 4: Manufacturing and Defense Industrial Base Risk Framework

Figure 5 provides additional detail regarding the risk framework. Columns one and two illustrate how macro forces such as budget sequestration or the decline of general U.S. manufacturing capabilities and capacity bear down on the manufacturing and defense industrial base to generate ten "risk archetypes" (e.g., reliance on a sole source, fragile supplier, foreign dependency, product security, etc.). The risk archetypes result in various impacts on the manufacturing and defense industrial base, outlined in column three. Finally, column four provides the various categories of recommendations to reduce or eliminate risk.

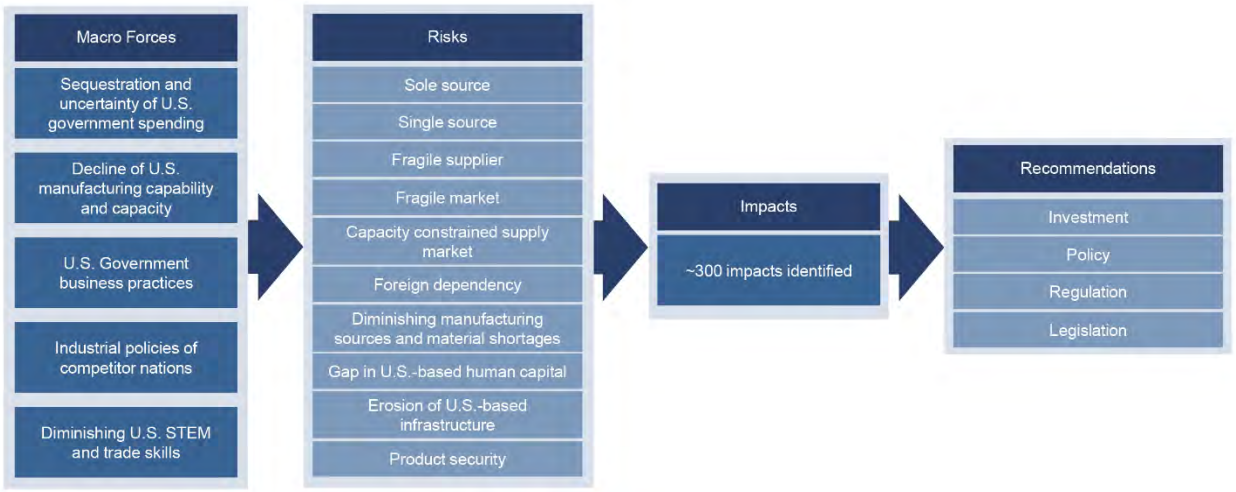


Figure 5: Detailed Outline of the Risk Framework

The risk framework illustrates the multifaceted mapping endemic in the 21st century manufacturing and defense industrial base. A single macro force, such as U.S. Government business practices or budget uncertainties, may map to multiple risk archetypes. Conversely, multiple macro forces may create a single risk archetype.

To demonstrate the interwoven aspects of the industrial base, consider the risks facing the aircraft sector, which include sub-sectors such as fixed wing, rotorcraft, and unmanned aerial systems. Each sub-sector faces challenges, including long product and system development timelines, high development and qualification costs, and production limitations. The challenges in the aircraft sector are driven by multiple risk archetypes, including single and sole source suppliers and gaps in U.S.-based human capital with expertise in critical hardware and software design capabilities. Collectively, these impacts could potentially reduce America's capability to produce and field an aircraft fleet with superior capabilities.

Such complex interactions between multiple risk archetypes are illustrated in Figure 6, which provides the count of each risk archetype by the sector working groups, found over the course of this assessment.

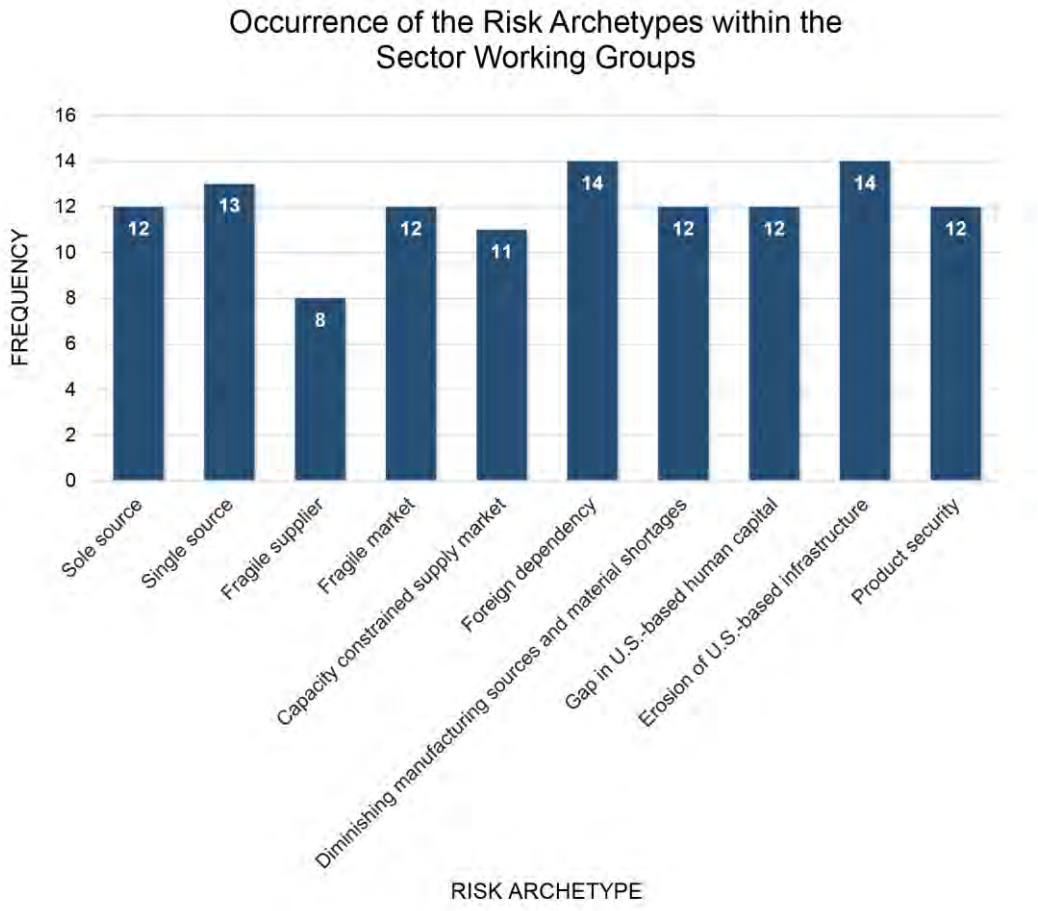
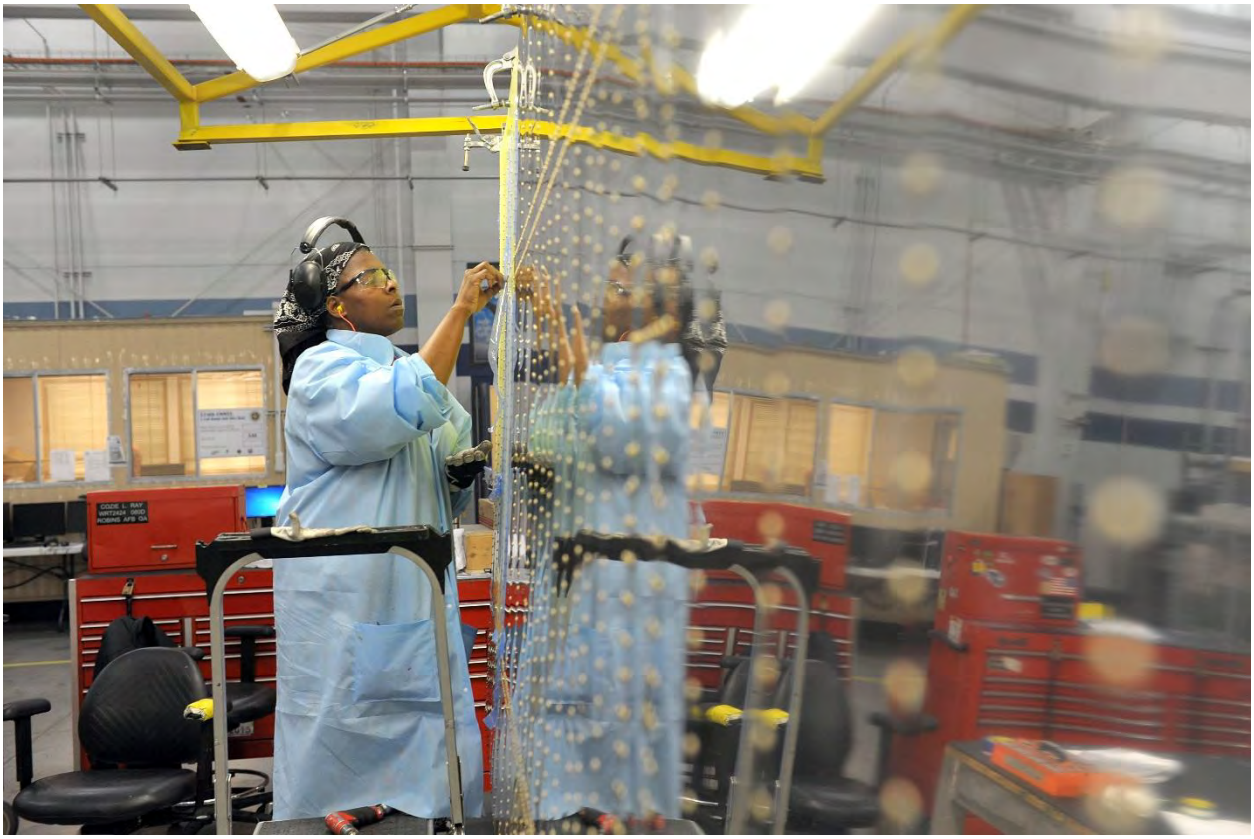


Figure 6: Risk Archetype Analysis across the Working Groups

In all, the working groups of the DoD-led Interagency Task Force identified almost 300 impacts across the ten risk archetypes in the manufacturing and defense industrial base. A classified spreadsheet with risk archetypes and impacts for all sixteen sectors is available.[§]

The ultimate goal of EO 13806 was to conduct a comprehensive assessment of the industrial base and develop a set of specific, actionable recommendations to mitigate or eliminate the identified impacts. In pursuit of this goal, the working groups relied on data and assessments from each of the coordinating agencies; qualitative feedback from industry listening sessions; support from the Defense Science Board; and modeling and analysis from the Institute for Defense Analyses, a federally-funded R&D center contracted by DoD for support of the assessment. Appendix Three lists the agencies and offices who supported the assessment; Appendix Four provides a full list of government resources referenced; Appendix Five lists the industry listening sessions.

[§] Given its proliferation throughout traditional sectors, the software engineering working group assessed impacts across sectors; as such, software risks are included in each of the sectors' inputs to the classified spreadsheet, not as its own inputs.



IV. An Overview of America's Manufacturing and Defense Industrial Base

America's manufacturing and defense industrial base consists of the end-to-end set of capabilities, both private and public, that design, produce, and maintain the platforms and systems (hardware and software) on which our Warfighter depends. With an extensive, multi-tiered global supply chain, the industrial base encompasses the extraction and refinement of primary materials, the manufacturing of components and parts, and the integration and sustainment of defense platforms and systems. It relies on a geographically and economically diverse network of private sector companies, R&D organizations, academic institutions, and government-owned facilities to develop and produce the technologies enabling U.S. military dominance and ensuring national security.

The Domestic Manufacturing and Defense Industrial Base

For the purposes of this assessment, the domestic industrial base includes two categories of producers of goods and services – the private sector and the organic industrial base. The private sector (also known as the commercial sector) includes prime system integrators, major sub-system suppliers, component suppliers, and service providers, from small to large companies. Across multiple tiers of the supply chain, private sector companies produce defense-specific products exclusively for use by DoD and approved foreign buyers, including platforms, weapons systems, and components hardened for defense uses. Private sector companies may also produce products specially designated as "dual-use," which have both military and nonmilitary applications and may be subject to export control, as well as commercial items without an explicit defense use.[7]

The organic defense industrial base (also known as the organic base, or the government or public sector) includes government-owned, government operated and government-owned, contractor operated facilities that provide specific goods and services for DoD. The organic base is composed of resource providers, acquisition and sustainment planners, and manufacturing and maintenance performers at depots, manufacturing arsenals, and ammunition plants. By law, some production and maintenance activities must be executed by organic base components.

The Global Manufacturing and Defense Industrial Base

The global elements of America's manufacturing and defense industrial base include enterprises from countries with formal supply relationships with the United States (U.S.) and those without.

The National Defense Authorization Act for FY1993 established the National Technology and Industrial Base, codifying the highly integrated defense industrial cooperation between the U.S. and Canada dating back to the Ogdensburg Declaration of 1940 and subsequent Hyde Park Declaration of 1941.[8] The National Defense Authorization Act for FY2017 added the United Kingdom of Great Britain and Northern Ireland and Australia to the definition of the National Technology and Industrial Base.[9] These types of agreements with partners and allies provide economies of scale and scope, help facilitate cost-effective defense production, and increase Warfighter interoperability.[10]

Some U.S. partners and allies outside the National Technology and Industrial Base are uniquely vetted and qualified to produce goods and services for DoD via secure defense procurement agreements. Bilateral Security of Supply arrangements allow DoD to request priority delivery for DoD contracts, subcontracts, or orders from companies in these countries, and allow the signatory nations to request priority delivery for their contracts and orders with U.S. firms. Security of Supply arrangements are conducted under the overarching Declarations of Principles for Enhanced Cooperation in Matters of Defense Equipment and Industry signed with participating nations. These arrangements encourage participating nations to acquire defense

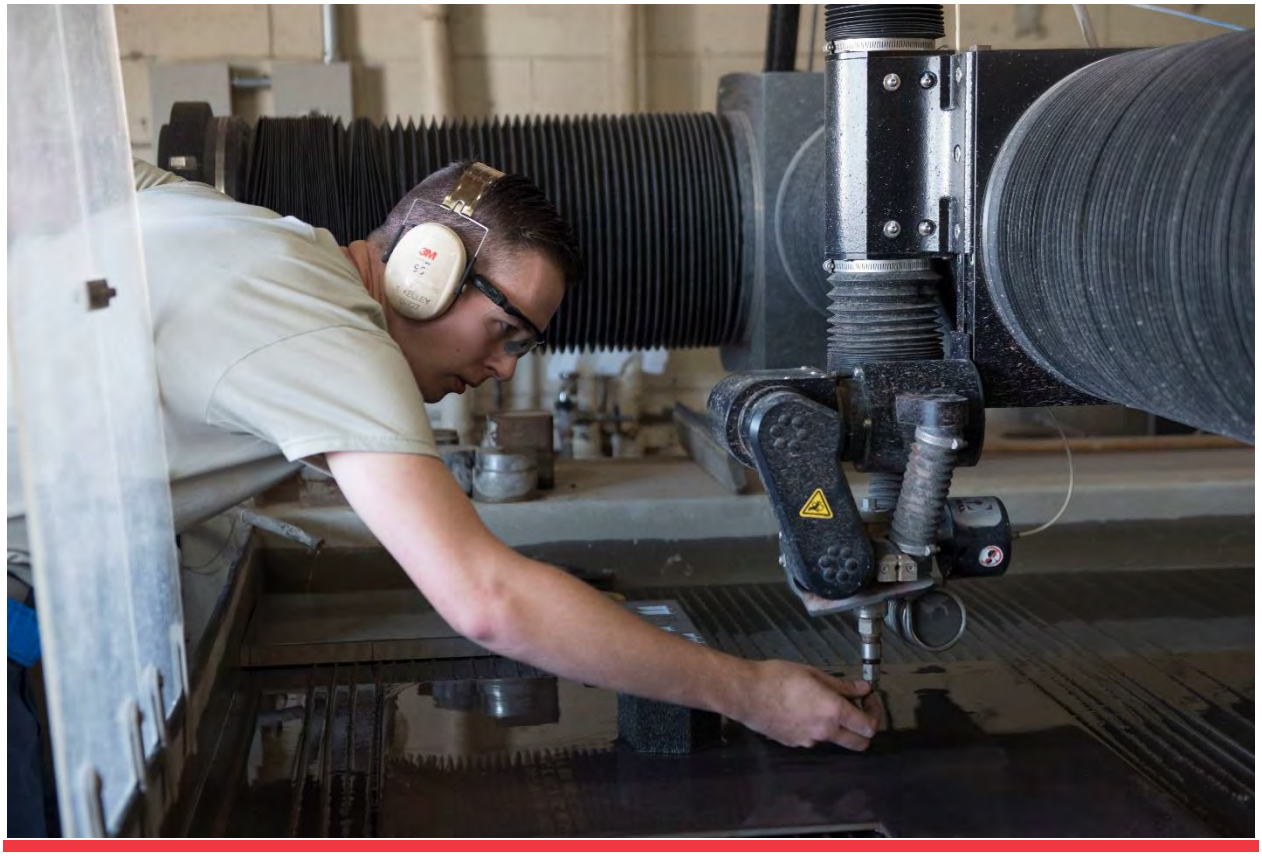
goods from each other, promote interoperability, and provide assurance of timely delivery during peacetime, emergencies, and armed conflict. Security of Supply arrangements are currently in place with Australia, Canada, Finland, Italy, Netherlands, Norway, Spain, Sweden, and the United Kingdom.

Under Reciprocal Defense Procurement Agreements, countries afford each other certain benefits on a reciprocal basis, consistent with their national laws and regulations. Each Reciprocal Defense Procurement agreement provides a framework for ongoing communication between or among DoD and its respective counterparts regarding market access and procurement matters that contribute to effective defense cooperation. Key Reciprocal Defense Procurement agreement principles include: fair competition, reduced market barriers, transparent processes, and protection of intellectual property. In addition, U.S.-based subsidiaries of foreign defense companies are able to leverage the support, intellectual property, and design capabilities of their foreign parent companies, as well the U.S.-unique capabilities developed under special security agreements or a proxy voting trust. It should be noted that, in general, the U.S. maintains a positive trade balance for defense articles and services with countries who are signatories to Reciprocal Defense Procurement agreements.

Through the ongoing globalization of industrial supply chains and commodities markets, a number of countries without formal supply agreements support the manufacturing and defense industrial base with items such as strategic and critical materials, commercial off-the-shelf products, electronics, and some defense components. Countries in this category include Kazakhstan, Singapore, Jamaica, and strategic competitors like China.

The picture emerging from this geographically and economically diverse network of providers is of an American industrial base with multiple opportunities for growth and innovation, but increasingly dispersed and at risk from both domestic gaps and global forces.

This page intentionally blank.



V. Five Macro Forces Driving Risk into America's Industrial Base

The micro-level sector analyses of the working groups led to identification of five inter-related, but conceptually distinct, macro forces (Figure 7). These macro forces collectively represent the root causes of the ten risk archetypes and associated impacts on America's manufacturing and defense industrial base. We must address the five causes, and mitigate the risks and threats to our industrial base, in order to prevent further erosion of America's military dominance.

Macro Forces	Definition
Sequestration and uncertainty of U.S. Government spending	Inconsistent appropriations, uncertainty about future budgets, macro-level ambiguity in U.S. Government expenditures, and the effects of the Budget Control Act create market instability
Decline of U.S. manufacturing base capabilities and capacity	Reductions across the U.S. manufacturing and defense industrial base affect the viability of suppliers, overall capacity, and capabilities available domestically
Deleterious U.S. Government business and procurement practices	Challenges working with DoD and other U.S. Government customers, including contracting regulations, policies, barriers to entry, qualification challenges, programmatic changes, and other problems, can lead to adverse effects on suppliers

Macro Forces	Definition
Industrial policies of competitor nations	Domestic industrial and international trade policies of competitor nations, notably the economic aggression of China, directly or indirectly degrade the viability, capabilities, and capacity of the U.S. National Security Innovation Base
Diminishing U.S. STEM and trade skills	Gaps in American human capital, including a lack of STEM talent and declining trade skills, diminish domestic capabilities to innovate, manufacture, and sustain

Figure 7: Definitions of the Five Macro Forces Driving Risks into America's Industrial Base

1. Sequestration and Uncertainty of U.S. Government Spending

Markets thrive on predictability, allowing businesses to make informed decisions and invest in the future. Defense spending inherently fluctuates with the arming for conflict and subsequent drawdown and decrease of program funding. But as illustrated in Figure 8, these swings in funding can be very dramatic, particularly in the funding streams for weapon systems procurement and research, design, test, and evaluation.

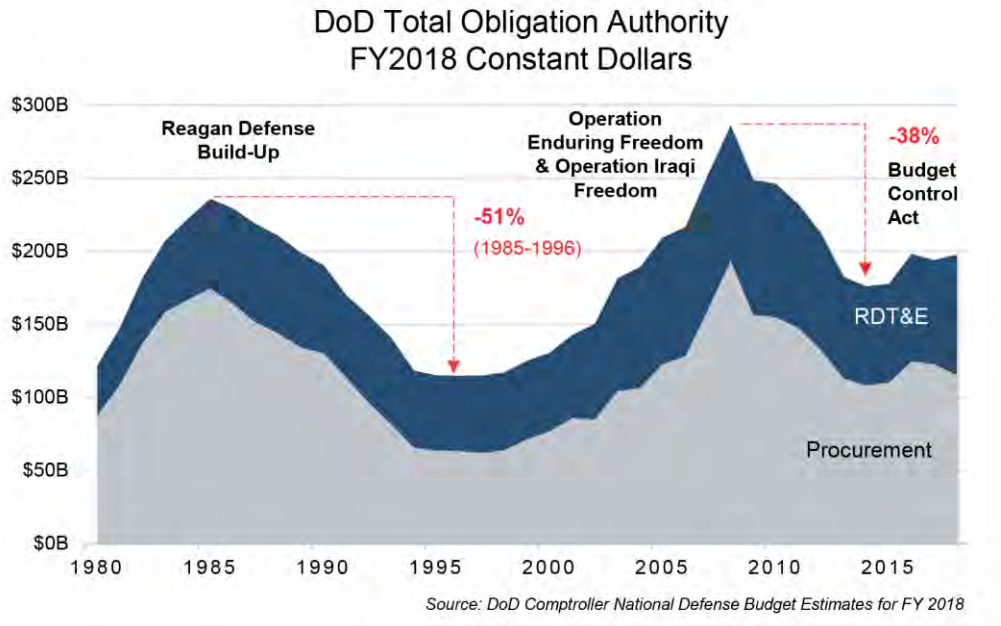


Figure 8: Defense Investment Spending From 1980 to 2017

A. Impacts of Budget Uncertainties

At the macroeconomic level, defense spending uncertainty makes predicting the overall market size difficult, impeding forecasting across every tier in the supply chain. Uncertainty in spending inhibits investment in capabilities even where the overall sector market size is increasing, impacting defense suppliers and leading to revenue fluctuation, capital investment

shortfalls, and suboptimal investment in R&D. Over time, spending instability also creates peaks of surge and valleys of drought – a pernicious, ambiguous pattern in which suppliers who build for scale production are left with excess capacity when programs end, creating long-term market distortion.

The decade-long reliance on Congressional continuing resolutions[11] has exacerbated uncertainty, both for DoD and across the supply chain. Combined with the adverse impacts of the Budget Control Act,[12] these fluctuations challenge the viability of suppliers within the industrial base by diminishing their ability to hire and retain a skilled workforce, achieving production efficiencies, and in some cases, staying in business. Without correcting or mitigating this U.S. Government-inflicted damage, DoD will be increasingly challenged to ensure a secure and viable supply chain for the platforms critical to sustaining American military dominance.

At the microeconomic level, DoD's budget within a specific sector does not imply uniform, stable, or even predictable funding for suppliers. Such uncertainty creates negative ramifications within specific industrial base sectors, even in periods with overall growth in spending. For example, when the Navy is unable to provide consistent orders for ships, niche suppliers of components such as controllers and actuators for nuclear powered ships cannot accurately project workloads, creating inconsistency and increasing risk for production capabilities.

Wrought aluminum plate, and specifically cold-rolled plate, is essential for armoring U.S. ground combat vehicles, constructing Navy ships, and building military aircraft. Unlike other more common forms of rolled aluminum materials, thick cold-rolled aluminum production capabilities and capacities are unique. DoD relies on domestic producers as well as capabilities available from ally countries in Europe. Due to U.S. Government budget uncertainties, unpredictable DoD demand, and other commercial market factors, the defense industrial base can face challenges when trying to balance diverse demands for cold-rolled plate production capacity while also informing long-term internal capital investment decisions.

Challenges facing the ground systems sector illustrate the relationship between budget uncertainty and diminishing workforce skills. Ground systems provide defense-unique products for mobility and firepower and are divided into tracked and wheeled vehicles for combat, combat support, and combat service support. Under the weight of budget uncertainties, the ground systems industrial base conducted incremental adoption of new technologies on legacy designs in order to maintain or modify current ground systems. While this approach allowed the military to defer the long schedules and high costs of new programs, it prevented ground systems development and maintenance personnel from experiencing the design to fielding lifecycle for a new system. This resulted in a generation of technicians, engineers, and scientists lacking experience in conceiving, designing, constructing, and integrating technologically advanced combat vehicles.

B. Production and Cost Inefficiencies

Fluctuations in defense procurement create production and cost inefficiencies. With confirmed procurement and investments, suppliers will take on high fixed costs to develop expensive new capacity in order to meet programmatic needs. When programs draw down, companies are left with highly specialized production capabilities that may go unused for decades. As defense-specific products require extensive qualification testing and procedures, suppliers face a costly decision to keep facilities open for potential future production, or to shutter facilities, incurring costs and forcing DoD to pay reconstituion costs when the need arises.

The "bullwhip effect" of DoD spending forces inefficiencies across the entire supply chain. As Figure 9 illustrates, the spike of recapitalization in space programs from 2000-2010, followed by a precipitous decline from 2010-2015, left suppliers with excess capacity.

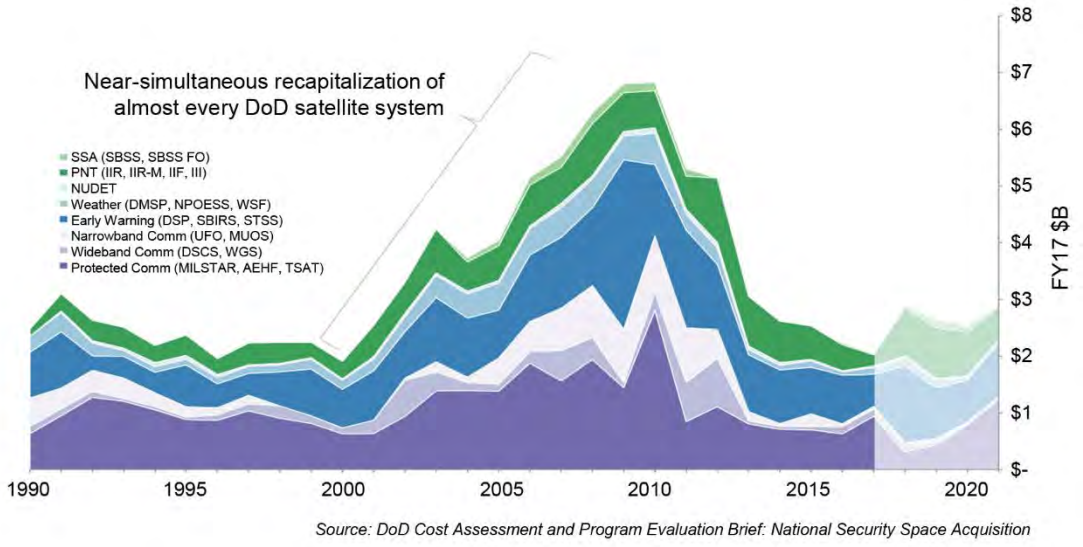


Figure 9: The Bullwhip Effect within the Space Programs

Fluctuations in capacity requirements acutely affect suppliers of maintenance and operations support services, to the detriment of readiness. For example, Navy ships have suffered maintenance availability delays and deferrals, reducing time underway and diminishing U.S. power projection. One study by the Rand Corporation found unpredictability in ship maintenance reduced incentives to invest in facilities and human capital, delaying needed modernizations and putting future surge maintenance capabilities at risk. Navy maintenance providers faced long periods of low workload coupled with short periods of surge, leading to cycles of hiring and layoffs that ultimately deterred skilled workers from the sector.[13]

A short history of the organic industrial base illustrates risk to overall readiness. The organic base, consisting of 17 major organic (government-owned, government operated) depot maintenance facilities and three manufacturing arsenals, provides maintenance and

manufacturing services to sustain approximately 440,000 vehicles, 780 strategic missiles, 278 combatant ships[14], and almost 14,000 aircraft.[15]

Since 2001, DoD has operated at a very high tempo with unprecedented system usage in support of global deployments, changing previously accepted formulas that compute maintenance requirements. Of $587.9 billion total DoD expenditures in FY 2015,[16] $73.4 billion was for maintenance – aircraft represented $25 billion, followed by ships at $16.8 billion, and vehicles at $7.7 billion.[17] Overuse and underfunding in infrastructure and workforce has eroded materiel readiness levels and facility conditions, directly impacting DoD's ability to repair equipment and materiel quickly to ensure availability for training and future deployments.

C. Harming Maintenance, Slowing Modernization

Continuing resolutions and the ongoing threat of sequestration exacerbate problems induced by defense spending uncertainty and hamper DoD's ability to develop a more lethal force. After the Budget Control Act of 2011, which introduced sequestration of the defense budget, DoD's procurement budget dropped 26% from its FY 2010 peak.[18] This rapid decrease in spending has negatively impacted operations, maintenance, and modernization of U.S. forces and directly impacted the viability of suppliers in the industrial base.

A recent study by the Center for Strategic and International Studies estimates that from 2001 to 2015, 17,000 companies ceased to be prime vendors for DoD.[19] Specialty manufacturers critical to the production of defense platforms have been especially hard hit and many are unable to make the modernization investments necessary to meet product requirements. For example, the single domestic source for large thin wall castings for rotary wing gearboxes filed for bankruptcy in 2016,[20] putting programs such as the AH-64E Apache, the V-22 Osprey, and the CH-53K Heavy Lift Replacement Helicopter at risk.

Unstable appropriations over the past decade created additional uncertainty in DoD's procurement plans, leading to unreliable demand signals to industry. Congress enacted over 30 continuing resolutions since 2009, with an average of 127 days each year under a continuing resolution (Figure 10), thus inhibiting long-term planning and postponing multi-year funding obligations to new programs.[21]

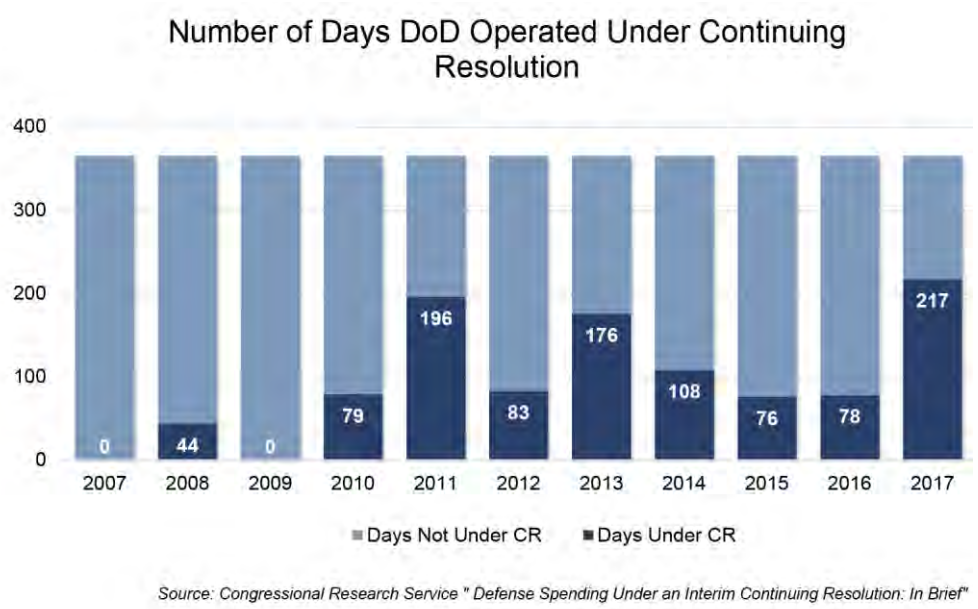


Figure 10: Duration of DoD Operations Subject to Continuing Resolution

D. Reducing Market Entry, Spurring Market Exits

In 2017, DoD found 75 new program starts that could not be executed while it continued to operate under a continuing resolution, with multiple tiers of the manufacturing and defense industrial base's supply chain taking the brunt of the impact.[22] Companies that do not have existing relationships are further deterred from entering into business with the DoD due to the level of cost and volatility associated with the engagement, thus impacting the potential of new entrants into the market.

The Government Accountability Office reported a "non-traditional" defense company that produces augmented reality products received funding to support engineering and development activities by the Army. However, due to budget sequestration, the funding was lost and the company is no longer pursuing business in the defense market.[23]

2. Decline of U.S. Manufacturing Capabilities and Capacity

The roots of America's defense industrial base are planted in the broader manufacturing ecosystem. Not only is the manufacturing sector the backbone of U.S. military technical advantage, but also a major contributor to the U.S economy, accounting for 9% of employment, 12% of GDP, 60% of exports, 55% of patents, and 70% of U.S. R&D.[24] The National Security Strategy highlights the importance of a vibrant manufacturing sector to comprehensive national power, while warning of the dangers inherent in the weakening of America's manufacturing base:

> *A healthy defense industrial base is a critical element of U.S. power and the National Security Innovation Base. The ability of the military to surge in response to an emergency depends on our Nation's ability to produce needed parts and systems, healthy and secure supply chains, and a skilled U.S. workforce. The erosion of American manufacturing over the last two decades, however, has had a negative impact on these capabilities and threatens to undermine the ability of U.S. manufacturers to meet national security requirements. Today, we rely on single domestic sources for some products and foreign supply chains for others, and we face the possibility of not being able to produce specialized components for the military at home. As America's manufacturing base has weakened, so too have critical workforce skills ranging from industrial welding, to high-technology skills for cybersecurity and aerospace. Support for a vibrant domestic manufacturing sector, a solid defense industrial base, and resilient supply chains is a national priority.*[25]

Between 2000 and 2010, over two-thirds of U.S. manufacturing saw production declines in terms of inflation-adjusted output.[26] While multi-factor productivity in manufacturing grew on an average of 2% per year from 1992-2004, productivity has declined an average of 0.3% per year from 2004 through 2016, implying diminishing economies of scale from inputs including labor, capital equipment, energy, materials, and purchased services.[27] Between 2000 and 2010 alone, the U.S. lost over 66,000 manufacturing facilities.[28] While the U.S. has seen an uptick in manufacturing, adding around 380,000 jobs since January 2017,[29] much work remains to be done to remedy years of decline in the sector.

From 2000-2018, many defense-relevant sectors have seen increased import penetration with rates more than doubling for the industrial controls and machine tools subsectors.[30] Since 2010, critical manufacturing and defense industrial base areas have seen fluctuations in obligations spending, creating variability in vendor counts and in many cases leading to lower domestic competition and further deteriorating DoD's supply chain (Figure 11). The negative effects of sequestration and the budget caps shocked the market and accelerated the downward trend in vendor counts, resulting in an estimated 20% decline in the number of prime vendors.[31]

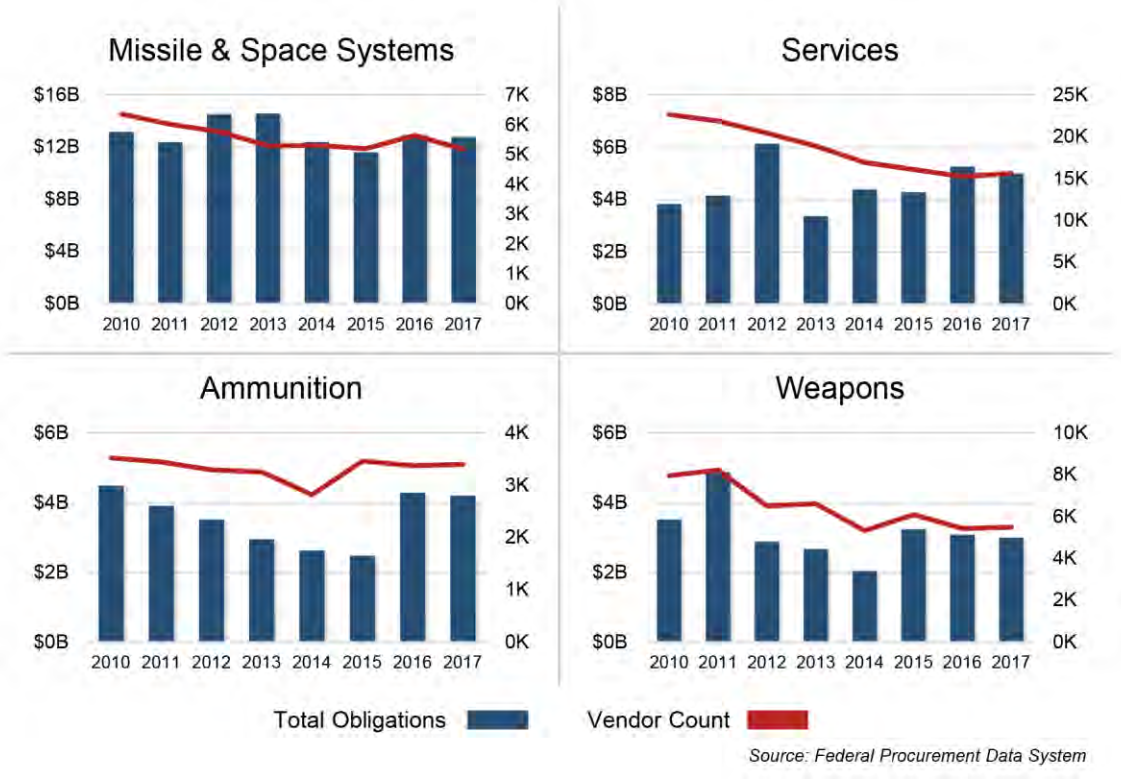


Figure 11: Falling Vendor Counts in Key Manufacturing and Defense Industrial Base Areas

Although America's traditional manufacturing base still accounts for an outsized benefit to the economy, decreases in key production capabilities, declines in manufacturing employment, and slow output growth for many manufacturing sectors have created key vulnerabilities and weaknesses that potentially threaten the nation's defense-related manufacturing capabilities. Since 1990, small and medium sized businesses – which make up a majority of U.S. manufacturing and employ a large portion of workers in the sector – reported declines in revenue growth, despite the largest manufacturing firms posting more than 2% annual growth.[32] The next generation of weapons will require advanced software, artificial intelligence, and machine learning, but traditional manufacturing processes continues to build the systems, platforms, and munitions that deliver kinetic effects. Both aspects of the industrial base are needed for long term economic growth and national security.

The decline in the U.S. manufacturing industry, relative to prior periods of great power, creates a variety of risks for America's manufacturing and defense industrial base and, by extension, for DoD's ability to support national defense. Risks range from greater reliance on single sources, sole sources, and foreign providers to workforce gaps, product insecurity, and loss of innovation.

A. Gaps in America's Manufacturing Workforce

With the weakening of the U.S. manufacturing sector, the American manufacturing workforce has suffered, with employment peaking in 1979 and job losses accelerating significantly in the 2000s.[33] As shown in Figure 12, the share of employment attributed to manufacturing has fallen

dramatically, from over 30% in the 1950s to less than 10% in 2017. From 1979 to 2017, the U.S. lost 7.1 million manufacturing jobs, 36% of the industry's workforce,[34] with more than 5 million manufacturing jobs lost since 2000 alone.[35] Job losses have been most pronounced in vital sectors subject to import competition, including primary metals, electronics, chemicals, and machinery.[36] Manufacturing and defense industrial base companies' inability to hire or retain U.S. workers with the necessary skill sets has led to significant gaps in skilled labor.

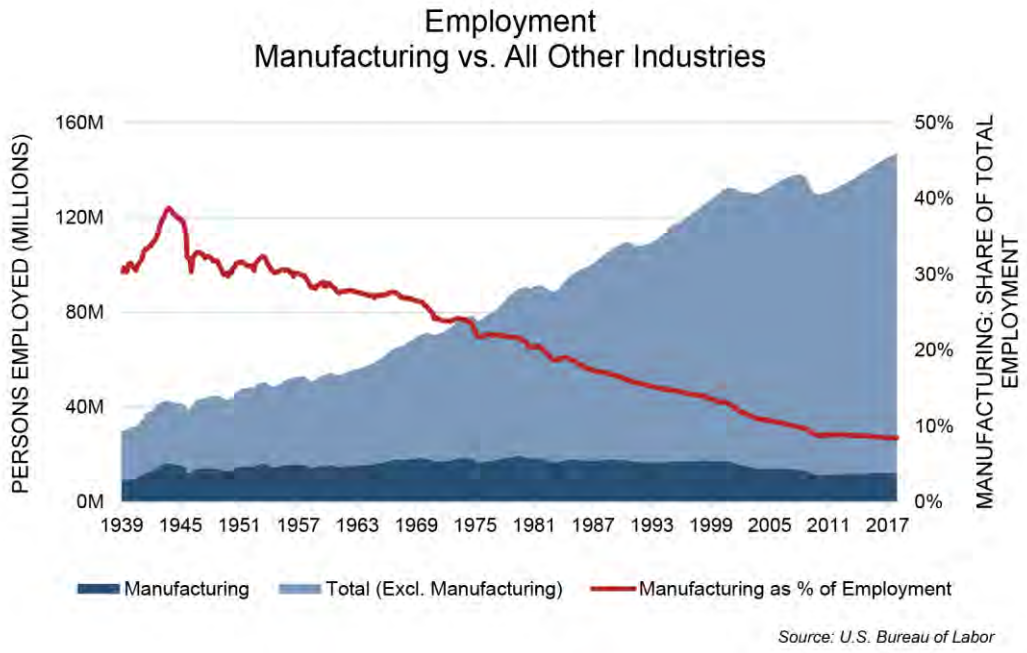


Figure 12: A Sharp Relative Decline in Manufacturing Employment in the U.S. Economy

A lack of skilled manufacturing workers and a decreasing number of jobs is destabilizing workforce readiness and leading to skill atrophy. As illustrated in Figure 13, such instability and atrophy further increase the gap between job openings and hires and accentuate the effects of a shrinking workforce, making worker placement more challenging even when labor is needed.

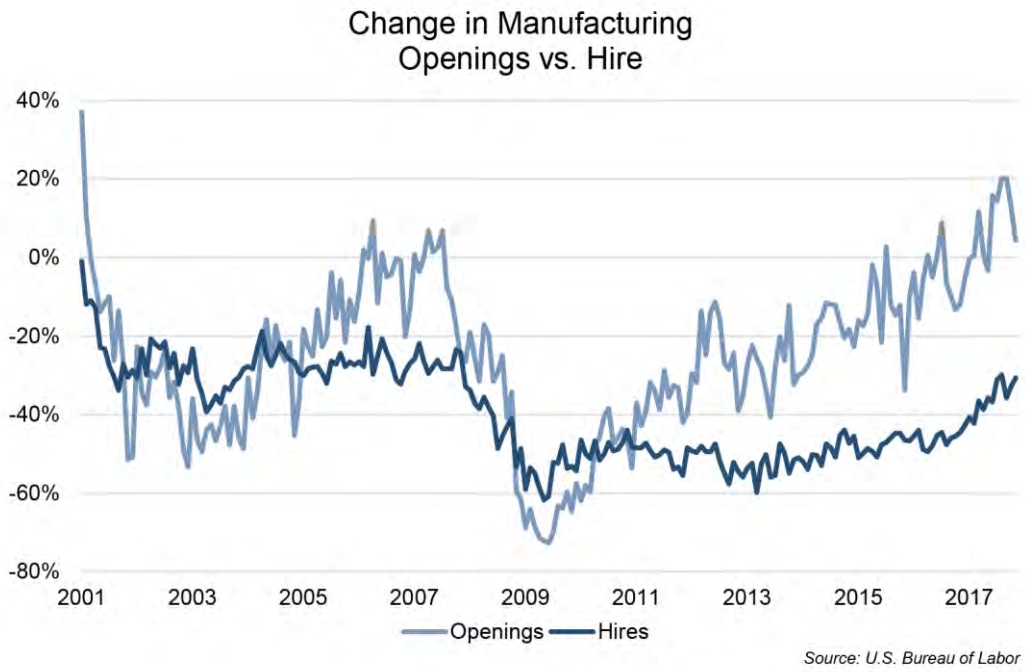


Figure 13: A Rising Gap between Job Openings and Hires

B. Decoupling of Design and Manufacturing

As U.S. companies lost their domestic supplier ecosystems, design decoupled from manufacturing and many firms shifted focus from designing and building products to designing and selling products. With increased offshoring of manufacturing, many companies have excised their process engineering capabilities, further reducing technical innovation and deterring future investment in next generation manufacturing.[37] Together, these effects jeopardize the ability of America's manufacturing base to supply innovative products and skilled workers to the industrial base, threatening capabilities needed for national security.

C. The Loss of Production of Strategic and Critical Materials

As part of the increasingly global manufacturing and defense industrial base, imports of strategic and critical materials, such as rare earths, have increased, causing a trade-off between supply dependency and lower costs. Rare earths are critical elements used across many of the major weapons systems the U.S. relies on for national security, including lasers, radar, sonar, night vision systems, missile guidance, jet engines, and even alloys for armored vehicles.[38] A 2016 study by the Department of Commerce's Bureau of Industry and Security reported that 66% of respondents, the majority of whom are vendors to DoD, indicated they imported rare earth or related materials.

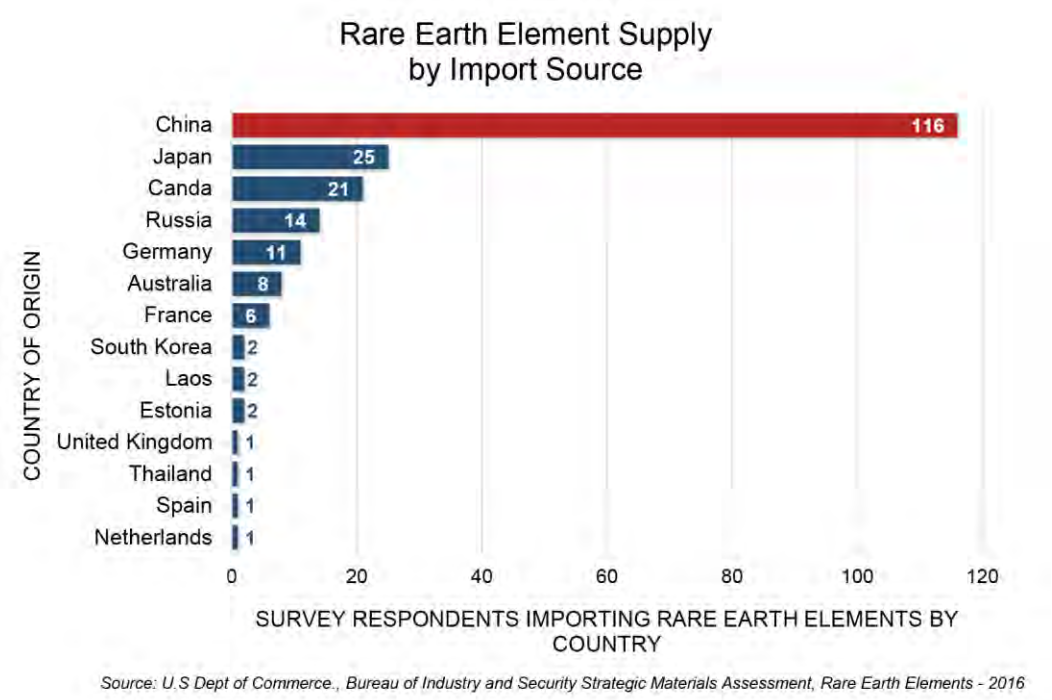


Figure 14: 2016 Rare Earth Element Imports

China's domination of the rare earth element market (Figure 14) illustrates the potentially dangerous interaction between Chinese economic aggression[39,40] guided by its strategic industrial policies and vulnerabilities and gaps in America's manufacturing and defense industrial base. China has strategically flooded the global market with rare earths at subsidized prices, driven out competitors, and deterred new market entrants. When China needs to flex its soft power muscles by embargoing rare earths, it does not hesitate, as Japan learned in a 2010 maritime dispute.[41]

D. Increased Risk of Counterfeits and Infiltration

A global industrial base means increased supply chain risk associated with foreign provision, including counterfeits, lack of traceability, and insufficient quality controls throughout supply tiers. The Department of Commerce's Bureau of Industry and Security surfaced several vulnerabilities in the electronics supply chain, including counterfeits (Figure 15), a lack of traceability, and insufficient quality controls throughout supply tiers. Imports of electronics lack the level of scrutiny placed on U.S. manufacturers, driving lower yields and higher rates of failures in downstream production, and raising the risk of "Trojan" chips and viruses infiltrating U.S. defense systems.[42]

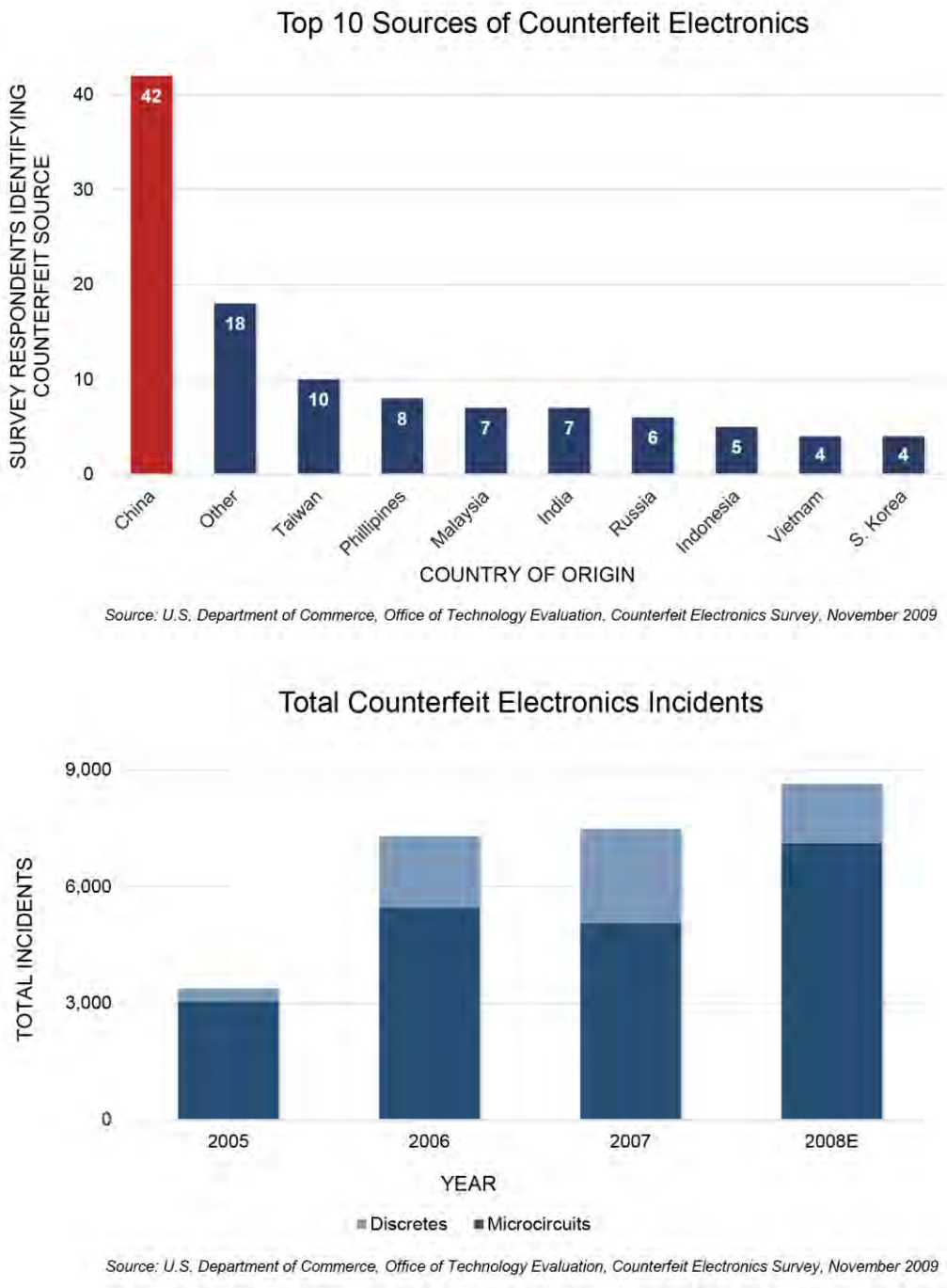


Figure 15: Counterfeit Electronics Dominated by China

E. Diminishing Technical Innovation Ecosystem

Decreased emphasis on domestic manufacturing threatens technical innovation and thereby America's ability to capture emerging technologies. A reduced domestic manufacturing footprint reduces incentives and the ability of companies to invest in new capabilities and

process improvements, further deteriorating industrial base capabilities critical to maintaining a global advantage.

Many technology-intensive multinational corporations have established R&D facilities in countries like India and China [43] for access to cheap, high skilled labor. As part of its industrial policy aggression, China has forced many American companies to offshore their R&D in exchange for access to the Chinese market.

As technical innovation moves abroad, changing rules around intellectual property development will impede U.S. access to the latest manufacturing technologies and decrease overall competitiveness. At risk is America's loss of leadership in industries of the future such as artificial intelligence, quantum computing, and robotics. Over the remainder of this century, these emerging industries will help redefine the battlefield.[44]

F. Reduced Competition

The shipbuilding sector illustrates how a decline in U.S. manufacturing, coupled with budget sequestration, impacts the industrial base. Shipbuilding includes construction and maintenance of Navy aircraft carriers, submarines, surface ships, and their associated weapons and command and control systems; today, the U.S. shipbuilding industrial base consists primarily of seven shipyards owned by four companies and their suppliers.

Shipyards – fixed facilities with dry-docks and fabrication equipment – support ship construction, repair, conversion and alteration, and the production of refabricated ship sections and other specialized services. The industry also includes manufacturing and other facilities beyond the shipyard, which provide parts and services for shipbuilding activities.

Industries involved in the manufacturing of shipbuilding components were among the hardest hit by the global shift in the industrial base over the last 20 years. Of the top ten highest grossing industries in Navy shipbuilding, six are in the manufacturing sector. Since 2000, these industries experienced a combined decline of over 20,500 establishments in the U.S.

Contraction of the shipbuilding sector limits competition among U.S. suppliers of Navy components. In many cases, competition has altogether vanished, forcing the Navy to rely on single and sole source suppliers for critical components. These companies struggle to survive and lack the resources needed to invest in innovative technology. Expanding the number of companies involved in Navy shipbuilding is important to maintaining a healthy industrial base that can fulfill the 355 ship fleet and support the Navy's long range shipbuilding plan.

Machine tools are power-driven machines used to shape or form parts made of metal, plastic, or composites to support both production and prototyping operations. Critical to creating modern defense and non-defense products, machine tools impact the entire supply chain and multiple sectors. The U.S. once led the world in the innovation and capacity of its high-end machine tools sector, but U.S. standing has dropped significantly since 2000. Key changes in machine tool consumption affected global patterns of production. Until the mid-2000s, China accounted

for no more than 15% of global machine tool consumption. By 2011, China's machine tool consumption accounted for 40% of the global total.[45] As its need for machine tools increased, China leveraged its low cost of capital and labor to build domestic machine tool factories and required foreign companies to execute joint ventures to access the Chinese market. The combined effects of the 2008 recession and a general trend of industry consolidation further reduced the number of machine tool manufacturers. In 2015, China's global machine tool production skyrocketed to $24.7B,[46] accounting for 28% of global production,[47] while the U.S. accounted for only $4.6B, after China, Japan, Germany, Italy, and South Korea.

These challenges to the overall manufacturing sector reduce the capability and capacity of U.S. defense production, with potential long term ramifications on the industrial base, national security, and the U.S. economy.

3. Deleterious U.S. Government Business and Procurement Practices

DoD business practices play a critical role in shaping the manufacturing and defense industrial base and can have an outsized effect on supplier behavior and viability.

Many of the current policies and practices of the U.S. Government, and DoD in particular, strain the industrial base and reduce incentives to supply to DoD,[48] resulting in an inability to meet national security demands, increasing foreign vulnerabilities, and a DoD challenged to meet its goals in an era of expanding strategic competition.[49]

A. Procurement Complexity and Lengthy Contract Timelines

In the late 1970s, DoD had 79 offices issuing procurement regulations totaling over 30,000 pages.[50] Currently, the Office of the Under Secretary of Defense for Acquisition and Sustainment is the single office issuing all Defense Federal Acquisition Regulation Supplement guidance. Consolidation of acquisition authority in one office, coupled with ongoing efforts supporting regulation reform such as the “Section 809 panel,” demonstrate increased vigor by DoD to streamline acquisition policy and processes. The “Section 809 panel,” created in the National Defense Authorization Act for FY2016, recently submitted the first of three volumes of its report outlining how DoD can further streamline acquisition processes.[51]

The Government Accountability Office notes that commercial companies are generally unaware of the best channels to propose business solutions to DoD. Overarching challenges noted by non-traditional companies seeking to conduct business with DoD include the complexity of the acquisition process, an unstable budget environment, lengthy contracting timelines, and inexperienced DoD contracting officials.[52] While some of the challenges may actually exist, opportunities abound to overcome misunderstandings about doing business with DoD, through education and communication between industry and the government.

B. Bespoke Accounting Standards and Burdensome Security Clearance Processes

In a recent study, the Defense Business Board highlighted the issue of DoD's Cost Accounting System[53] and emphasized Federal Acquisition Regulation Part 15 "Contract by Negotiation."[54] Federal Acquisition Regulation Part 15 is only one of many acquisition methods but is often inflexible and requires strict adherence to DoD's Cost Accounting System, which requires private sector partners to either replace preexisting accounting systems or develop a parallel system in order to comply with federal requirements. Given other accounting requirements levied on private sector companies, such as those outlined in the Sarbanes-Oxley Act of 2002, requiring a customized accounting system creates the need for additional resources, for which many companies cannot make the business case.

A 2017 Government Accountability Office report highlighted the excessive time and cost associated with obtaining key certifications necessary for doing business with DoD, including meeting IT and software requirements.[55] A similarly lengthy process associated with obtaining security clearances for facilities and their personnel, most of which is the result of a backlog of personnel security investigations processing, often impedes suppliers of both hardware and software from exploring DoD as a client. Furthermore, requirements levied on companies under foreign ownership, control, or influence can discourage their participation in the National Industrial Security Program altogether. Operational and information security standards and whistleblower protections are important, but nonetheless impose additional costs that may increase barriers to entry.

C. Lengthy Acquisition and Development Timelines

Since the late 1980s, the median cycle time required to develop a major defense acquisition program has held steady at approximately eight years.[56] During this time, DoD has grown increasingly dependent on electronics and the commercial electronics market, which moves at a much faster pace of development and production. This slow cycle time is leading to increased obsolescence issues.

For example, given the eight-year cycle time for a major defense acquisition program, the U.S. Army Aviation and Missile Research, Development, and Engineering Center estimates that 70% of electronics procured by DoD are obsolete prior to system fielding.[57] There exists an opportunity for finding balance between requirements for system development and keeping pace with technology.

D. Requirements-Driven Rather Than Solutions-Oriented Acquisition Process

The prevalent business approach and organizational culture of the U.S. Government favors a top-down and requirements-driven process, often to the detriment of innovation. While it is possible to achieve technological breakthroughs or innovative capabilities through such a process, requirements-driven acquisition solicits solutions for specific capabilities rather than for outcomes, potentially imposing an opportunity cost on innovation.

There appear to be few opportunities for companies to offer services or capabilities that do not already fit within the DoD's stated requirements and scope.[58] The tendency to focus on requirements versus solutions, compounded by the various barriers to entry, cost of doing business, and skewed market incentives can inhibit competition and new entrants. Companies successful in the government contracting space are often necessarily structured to comport to federal guidelines, rules, and regulations and are typically unlikely to be able or incentivized to challenge the requirements-driven process.

4. Industrial Policies of Competitor Nations

U.S. defense products enjoy a very successful export market with $41.93B in FY2017 sales,[59] further bolstered by the Administration's efforts to help facilitate this critical part of our economy. However, the erosion of parts of our industrial base, is, in part, attributable to the industrial policies of major trading partners that have created an unfair and non-reciprocal trade environment. Those policies contribute to the U.S. annual trade deficit in goods, the largest in the world at more than $796 billion.[60] Of this total, almost half of the U.S. trade deficit in goods is with China – roughly $375 billion in 2017.[61] The European Union accounts for another roughly $150 billion.[62]

A. A Challenging Economic Playing Field

Many nation states have implemented coherent investment plans and tax policies, such as Germany's Industry 4.0 initiative, forcing U.S. firms to compete against nation states with well-resourced policies to support their domestic industries. In this environment, the lack of a coherent U.S. industrial policy puts domestic suppliers at a disadvantage, amplified by the trade policies of some U.S. competitors that violate trade norms of reciprocity and open competition.

The risks now facing the soldier systems sector help illustrate these challenges. Soldier systems includes a broad and diverse collection of products necessary to maximize the Warfighter's survivability, lethality, sustainability, mobility, combat effectiveness, and field quality of life by considering the Warfighter as a system. Between 1995 and 2009, the U.S. textile industry suffered historic contraction, and though the sector has improved since then, Asian markets now dominate global textiles supply.[63] According to a recent Department of Commerce survey, the greatest competitive disadvantages in the clothing and textile subsector are related to the workforce and raw material cost and/or availability.[64] Though U.S. industry has invested heavily to compete, increasing labor productivity by 60% since 2000,[65] total sales and exports of U.S. manufactured clothing and textile products have been stagnant from 2012-2016.[66] As wage growth has increased the price of labor in China, lower wage countries such as Pakistan and Vietnam have seen the most rapid growth in textile exports, reaching 9% growth in 2016.[67]

While the United States is the fourth largest exporter of textile-related products in the world, there remain acute challenges across the more than 8,000 products the domestic textile industry supplies to DoD.[68] The single qualified domestic source for high-tenacity polyester

fiber used in many DoD tent systems dissolved its business due to its inability to compete in an increasingly competitive global fibers and textiles market.[69] Currently, there is no U.S. manufacturing capability for high-tenacity polyester fiber that allows for military specification qualification.

B. China's Military Expansion and Modernization

While multiple countries pursue policies to bolster their economies at the expense of America's manufacturing sector, none has targeted our industrial base as successfully as China. China is engaged in economic competition with the U.S. and our allies[70] over key sectors of the global economy,[71] and China's strategies of economic aggression and its complementary military modernization efforts are codified in its doctrine of civil-military fusion. By actively promoting the fusion of its military and civilian industrial and science and technology sectors, Beijing strives to reinforce the People's Republic of China's capabilities to build the country into an economic, technological, and military power while ensuring that overall control of these elements of national power remain firmly in the hands of the Communist Party of China.

Since joining the World Trade Organization in 2001, China's real gross domestic product has grown more than 300%, from $2.4 trillion in 2001 to $10.2 trillion 2017.[72] During that period, U.S. real gross domestic product grew less than 40%, from $12.8 trillion in 2001 to $17.3 trillion in 2017 (Figure 16).

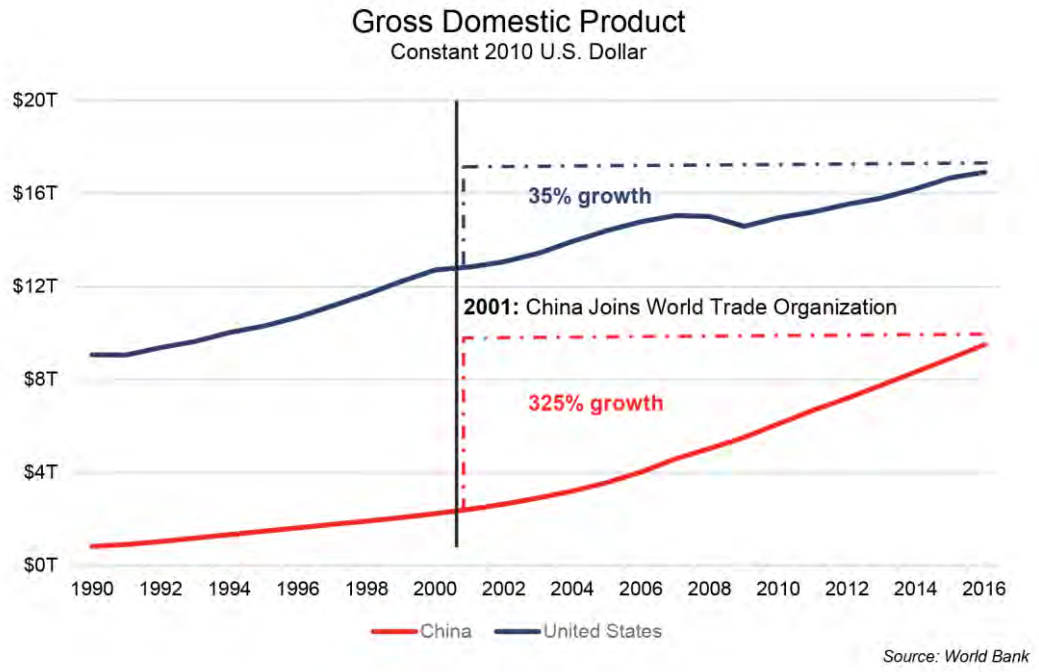


Figure 16: China Rapid Growth since Joining the WTO

China's economic growth has, in turn, helped finance its rapid military modernization. In 2001, China's annual military budget was less than $20 billion.[73] By 2017, it exceeded $150 billion,[74] second only to the U.S.

China's non-market distortions to the economic playing field must end or the U.S. will risk losing the technology overmatch and industrial capabilities that have enabled and empowered our military dominance – even as China seeks to raise its military capabilities to U.S. levels.

C. China's Strategies of Economic Aggression

One of the Chinese Communist Party's primary industrial initiatives, Made in China 2025,[75] targets artificial intelligence, quantum computing, robotics, autonomous and new energy vehicles, high performance medical devices, high-tech ship components, and other emerging industries critical to national defense.[76] In order to obtain the capabilities needed to support these advanced technologies, China relies on both legal and illicit means, including foreign direct and venture investments, open source collection, human collectors, espionage, cyber operations, and the evasion of U.S. export control restrictions to acquire intellectual property and critical technologies.

For example, China imposes conditional access to its domestic market to lure intellectual property, investment, and onshoring of manufacturing, using high tariffs and a complex web of non-tariff barriers, including restrictive customs barriers, burdensome licensing requirements, discriminatory regulatory standards, and local content requirements in government procurement to boost domestic manufacturing and production.[77] China also uses forced technology transfer[78] as a condition of access to the Chinese market.[79]

In an attempt to dominate critical global markets and manufacturing industries, China leverages policy tools such as low interest loans; subsidized utility rates; lax environmental, health, and safety standards; and dumping to boost its industry.[80] China also uses counterfeiting and piracy, illegal export subsidies, and overcapacity to depress world prices and push rivals out of the global market. It has implemented these tactics to capture much of the world's solar and steel industries and intends to extend its dominance to other industries such as automobiles and robotics.[81]

As a result of its successful assault on the U.S. solar industry,[82,83,84,85] China produces over 70% of the world's solar cells.[86] As the European Chamber of Commerce has documented, "for a generation, China has been the factory of the world," and by 2015, it already produced 24% of the world's power, 28% of the automobiles, 41% of the world's ships, over 50% of the refrigerators, over 60% of the color TV sets, over 80% of the air conditioners and computers, and over 90% of the mobile phones.[87]

A key finding of this report is that China represents a significant and growing risk to the supply of materials and technologies deemed strategic and critical to U.S. national security; a challenge shared by key allies such as Germany[88] and Australia.[89] In addition to China dominating many material sectors at the upstream source of supply (e.g., mining), it is increasingly dominating downstream value-added materials processing and associated manufacturing supply chains, both in China and increasingly in other countries. Areas of concern to America's manufacturing

and defense industrial base include a growing number of widely used and specialized metals, alloys and other materials, including rare earths and permanent magnets.

China is also the sole source or a primary supplier for a number of critical energetic materials used in munitions and missiles. In many cases, there is no other source or drop-in replacement material and even in cases where that option exists, the time and cost to test and qualify the new material can be prohibitive – especially for larger systems (hundreds of millions of dollars each).

From commodity materials to rare earths,[90] Chinese investment in developing countries in exchange for an encumbrance on their natural resources and access to their markets, particularly in Africa and Latin America,[91] adds an additional level of consideration for the scope of this threat to American economic and national security.

D. China's Soft Power Projection

Since China joined the World Trade Organization in 2001 and gained greater access to U.S. markets, the trade deficit in goods with China has grown from $83 billion to $375 billion in 2017.[92] China has historically used currency manipulation to artificially reduce the value of the yuan and increase the competitiveness of its exports.[93] To maintain its currency peg, China helps finance the chronic U.S. trade deficit through purchases of U.S. Government securities.[94] China has then leveraged its surplus-funded capital accounts to pursue aggressive trade and infrastructure policies such as the One Belt, One Road Initiative, a mercantile trade system promoting China's political domination of Eurasia and reducing U.S. market access.

Such policies further exacerbate the trade imbalance with the U.S. and have created similar imbalances with U.S. allies and partners – as illustrated in Figure 17.

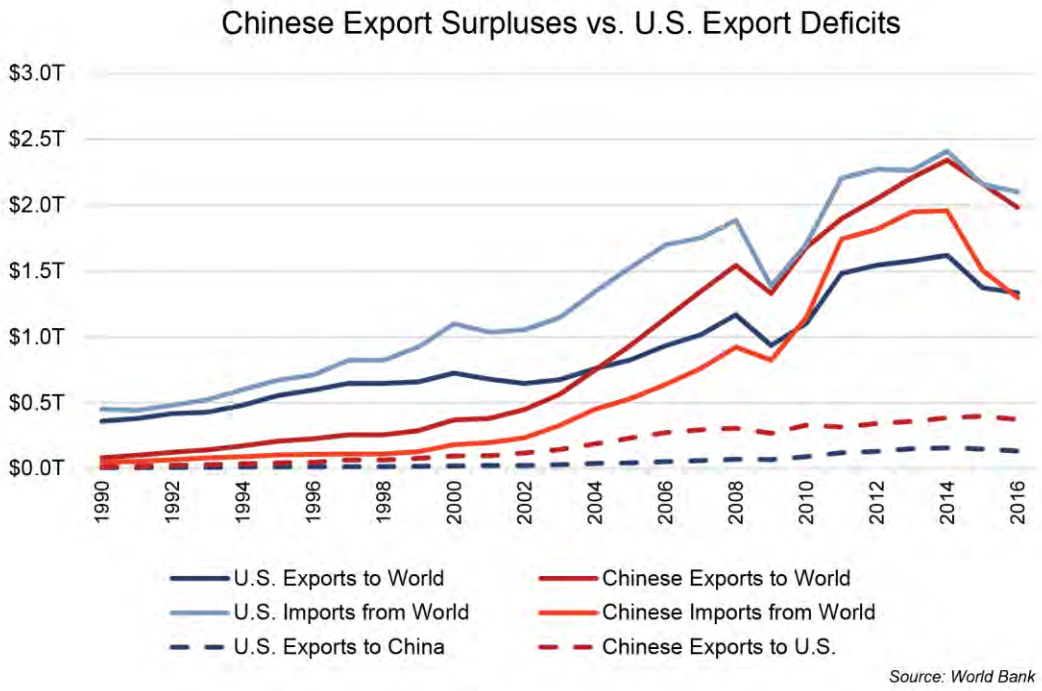


Figure 17: China's Trade Imbalances with the U.S. and Rest of the World

The significant asymmetry between the trade dependence of American allies in the Indo-Pacific versus China's economic dependence on these American allies and partners is further illustrated in Figure 18.[95] In recent years, China has not hesitated to leverage its asymmetric trade dominance to project soft power.

Country	% of Country's Exports Purchased by China	% of China's Exports Purchased by These Countries
Australia	33%	2%
Taiwan	26%	2%
South Korea	25%	5%
Japan	18%	6%
Malaysia	13%	2%
Singapore	13%	2%
Philippines	11%	<2%
Thailand	11%	2%

Source: World Bank

Figure 18: China's Rising Economic and Monopsony Power over American Allies

For example, after South Korea announced the placement of the U.S. Terminal High-Altitude Aerial Defense (THAAD) system, a key element of U.S. foreign policy and military strategy,

China undertook an aggressive economic warfare campaign against Seoul.[96] China's campaigns of economic coercion have also been observed against other U.S. allies and partners, including a ban on Philippine bananas over territorial disputes in the South China Sea;[97] the aforementioned restriction of rare earth exports to Japan following the Senkaku Islands dispute in 2010;[98] persistent economic intimidation against Taiwan;[99] and the recent ceding of a Sri Lankan port.[100]

China's trade dominance and its willingness to use trade as a weapon of soft power increases the risks America's manufacturing and defense industrial base faces in relying on a strategic competitor for critical goods, services, and commodities.

E. China's Research and Development Spending Strategy

Although the bulk of China's early exports were dependent on low value-added manufacturing, Beijing has recognized that it must innovate to obtain long term dominance, as documented in the 2006 Medium to Long Range Plan for Science and Technology.[101] This and other state-authored policies explicitly recognize the need to capture advanced commercial technologies with military applications, and China has directed both state-owned enterprises and private sector investors to advance the military's access to cutting edge civilian research.[102] To advance this goal, China's current five year plan calls for increasing research and design spending to 2.5% of gross domestic product, up from 2.1% in 2011-2015. As Figure 19 illustrates, Chinese R&D spending is rapidly converging to that of the U.S. and will likely achieve parity sometime in the near future.

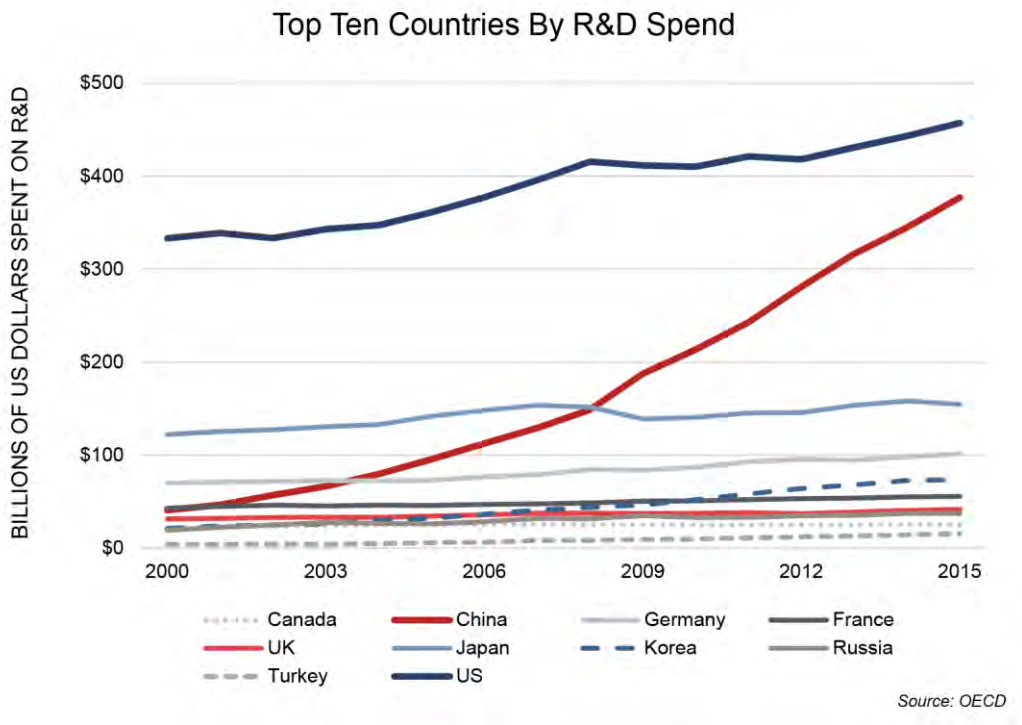


Figure 19: China's Rapid Growth in R&D Spending Relative to the Rest of the World

China's current plan also focuses on capturing a leading position in advanced foundational dual-use industries such as semiconductors, chip materials, robotics, aviation, and satellites. Additionally, China is investing in key foundational technologies—artificial intelligence, robotics, autonomous vehicles, augmented and virtual reality, financial technology, and gene editing—to enable a wide array of commercial and military applications. To advance its strategic goals, Beijing has unveiled several mega-projects (e.g., core electronics, high-end chips, quantum communications, next-generation broadband communications) that are likely intended to challenge the United States.[103]

As documented in the United States Trade Representative's *Findings Of The Investigation Into China's Acts, Policies, And Practices Related To Technology Transfer, Intellectual Property, And Innovation Under Section 301 Of The Trade Act Of 1974,*[104] China uses legal, extra-legal, and illicit[105] industrial policy tools and tactics to force or facilitate the transfer of technologies and intellectual property from U.S. and foreign companies to Chinese counterparts and competitors.[106] State-backed actors are buying and stealing differentiating intellectual property on an unprecedented scale, targeting key U.S. technology, infrastructure, and materials and exploiting the free-market system to access and acquire key components of the U.S. industrial base, leaving defense capabilities vulnerable.

In 2016, Chinese foreign direct investment in the U.S. was $46 billion, or triple the previous year and a ten-fold increase from 2011, demonstrating their all-of-nation long-term growth strategy in support of both economic and military power. China's cumulative foreign direct investment in the U.S. since 2000 now exceeds $100 billion.[107,108] Figure 20 illustrates how China is targeting key technology sectors with its state-supported foreign direct investment.

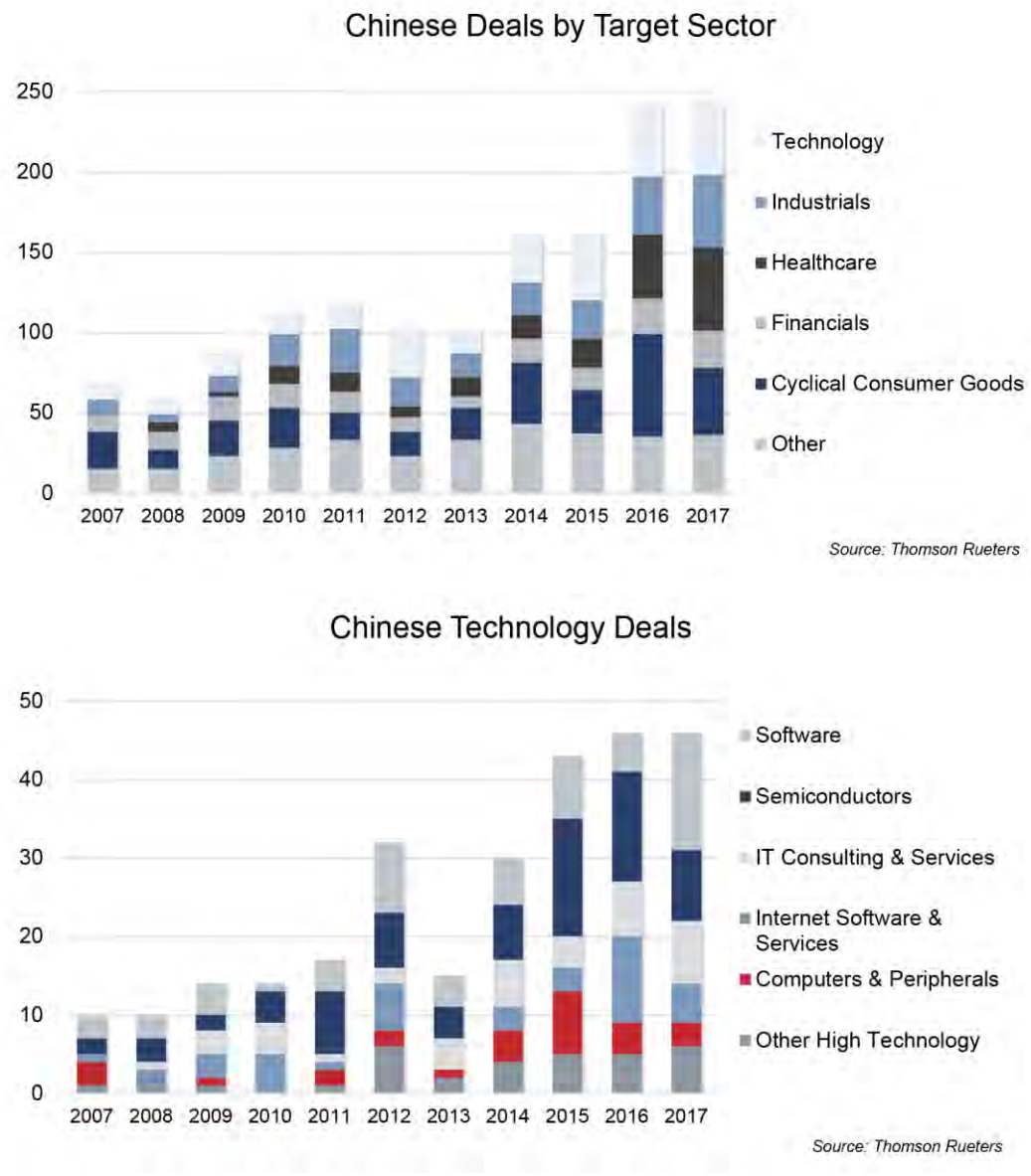


Figure 20: China Targets U.S. Technology with Its Outbound Foreign Direct Investment

China's capture of foreign technologies and intellectual property,[109] particularly the systematic theft of U.S. weapons systems[110] and the illicit and forced transfer of dual-use technology, has eroded the military balance between the U.S. and China.[111] Such transfers aid China's efforts to gain a qualitative technological advantage over the U.S. across key domains, including naval, air, space, and cyber.[112]

China's aggressive industrial policies have already eliminated some capabilities with critical defense functions, including solar cells for military use, flat-panel aircraft displays, and the processing of rare earth elements.[113] China's actions seriously threaten other capabilities, including machine tools; the production and processing of advanced materials like biomaterials, ceramics, and composites; and the production of printed circuit boards and semiconductors.[114]

As part of China's One Belt, One Road doctrine to project Chinese soft and hard power,[115] China has sought the acquisition of critical U.S. infrastructure, including railroads,[116] ports,[117] and telecommunications.[118]

China's economic strategies, combined with the adverse impacts of other nations' industrial policies, pose significant threats to the U.S. industrial base and thereby pose a growing risk to U.S. national security.

F. Strategic Materials and Printed Circuit Boards

Unlawful and otherwise unfair foreign trade practices (mostly by China) are injuring U.S. strategic and critical material manufacturers. Predatory practices – including state-sponsored dumping, public subsidies, and intellectual property theft – are destroying commercial product lines and markets of domestic DoD suppliers. The loss of commercial business can lead to the loss of domestic production capabilities essential to U.S. defense and essential civilian needs. Impacted materials are widely used across multiple DoD systems and all major defense sectors (land, sea, air, and space systems).

In multiple cases, the sole remaining domestic producer of materials critical to DoD are on the verge of shutting down their U.S. factory and importing lower cost materials from the same foreign producer country who is forcing them out of domestic production.

Without relief from unlawful and otherwise unfair trade practices, the U.S. will face a growing risk of increasing DoD reliance on foreign sources of vital materials.

The case of printed circuit boards likewise highlights the growing risks to the industrial base. The printed circuit board sub-sector provides the substrate and interconnects for the various integrated circuits and components that make up an electronic system. Today, 90% of worldwide printed circuit board production is in Asia, over half of which occurring in China; and the U.S. printed circuit board sub-sector is aging, constricting, and failing to maintain the state of the art for rigid and rigid-flex printed circuit board production capability.

With the migration of advanced board manufacturing offshore, DoD risks losing visibility into the manufacturing provenance of its products as many domestic manufacturers have offshore manufacturing facilities or relationships. In addition to the potential dissemination of design information, many of the offshore facilities do not meet or comply with DoD quality requirements.

5. Diminishing U.S. STEM and Trade Skills

Increasing globalization of the supply chain and a diminishing domestic manufacturing sector are combining to create human capital gaps and erosion of American capabilities. STEM knowledge and core trade skills are necessary to ensure the holistic and synergistic health of the

defense ecosystem. Skill gaps in both areas entail inherent risk, from a decline in production capacity to decreased innovation.

From 2006 to 2016, STEM occupations experienced large job growth – 52% of occupations grew in their total number of employees – while 74% of manufacturing occupations lost jobs.[119] Despite STEM occupations typically having greater educational requirements and hence drawing from a smaller labor pool, the top 10 occupations in those fields added more workers in absolute terms over the 2006-2016 time period than the top 10 manufacturing occupations, as ranked by absolute job growth (Figure 21).

Figure 21: STEM-Oriented Versus Core Manufacturing-Oriented Occupations

A. Demographic Challenge

While the population of manufacturing workers is aging at the rate of baby boomers across industry, the most concerning aspect of the manufacturing workers demographics is the decrease in workers in the 35-44 age range (Figure 22). In the prime of their careers and poised to internalize knowledge transfer from older workers, the loss of mid-career workers to other sectors poses a direct threat to the long-term viability of manufacturing. The risk that knowledge will fail to be transferred to new entrants into the labor market is rising, particularly in skilled production occupations, which account for over 50% of manufacturing workers.[120]

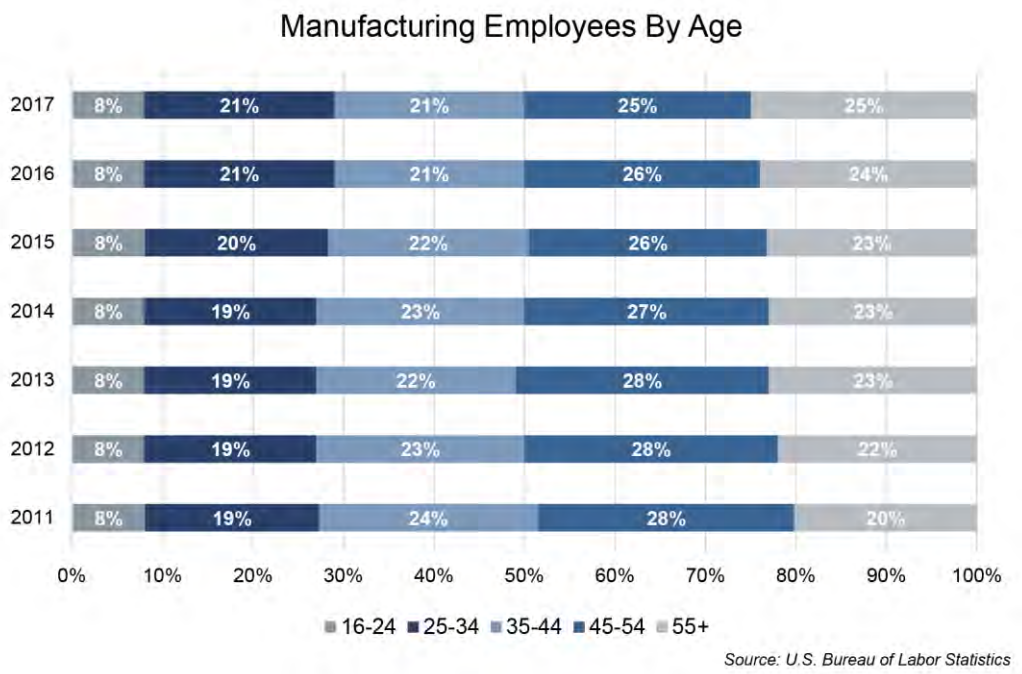


Figure 22: The Demographics of Manufacturing Employment

B. Growing Cultural Bias and Strategic Rivals

Some of the most challenging aspects in the manufacturing sector are recruitment and retention. In a recent manufacturing skills gap study conducted by the Manufacturing Institute and Deloitte, only one third of respondents indicated they would encourage their children to pursue a career in manufacturing. Gen Y (ages 19-33 years) respondents ranked manufacturing as their least preferred career destination.[121] Yet once a candidate is hired, the struggle continues. 79% of executives surveyed stated it is moderate to extremely challenging to find candidates to pass screening and/or the probationary period, [122] leaving them with employees unable to perform the work for which they were hired.

While the total number of bachelor's degrees in the U.S. has increased steadily in the last two decades, the number of STEM degrees conferred in the U.S. still pales compared to China.[123] In addition, the U.S. has seen an increase in students on temporary visas, many of whom would be unable to gain the security clearances needed to work in the defense ecosystem.[124]

Growth in advanced science and engineering degrees shows the U.S. graduating the largest number of doctorate recipients of any individual country, but 37% were earned by temporary visa holders[125] with as many 25% of STEM graduates in the U.S. being Chinese nationals.[126]

As the U.S. continues to attempt progress in STEM, ongoing Chinese support and influence continues to demonstrate strength in building a workforce of the future, while American universities are major enablers of China's economic and military rise.

VI. Ten Risk Archetypes Threatening America's Manufacturing and Defense Industrial Base

Figure 23 catalogues the ten risk archetypes, at the firm and market level, emerging from the EO 13806 assessment. While each of the risk archetypes may be viewed in isolation, sub-sets of risks tend to cluster and threaten American's manufacturing and defense industrial base.

The risk archetypes lead to a variety of negative impacts on America's industrial base, including reduced investment in both new capital and R&D; concomitant reductions in the rates of modernization and technological innovation; a loss of suppliers and potential bottlenecks across the many tiers of the supply chain; and lower quality and higher prices resulting from reduced competition.

At the production level, negative impacts also include cost inefficiencies, deferred maintenance, reduced reliability, and increased vulnerability to counterfeit components. Across the supply chain, these negative impacts can manifest as significant gaps in the industrial base, from single-points-of-failure and threatened capabilities to non-extinct and extinct capabilities. Ultimately, these negative impacts have the potential to result in diminished readiness, decreased lethality, insecurity of supply, program delays, and an inability to surge.

Risk Archetype	Definition
Sole source	Only one supplier is able to provide the required capability
Single source	Only one supplier is qualified to provide the required capability
Fragile supplier	A specific supplier is financially challenged / distressed
Fragile market	Structurally poor industry economics; potentially approaching domestic extinction
Capacity constrained supply market	Capacity is unavailable in required quantities or time due to competing market demands
Foreign dependency	Domestic industry does not produce the product, or does not produce it in sufficient quantities
Diminishing manufacturing sources & material shortages (DMSMS)	Product or material obsolescence resulting from decline in relevant suppliers
Gap in U.S.-based human capital	Industry is unable to hire or retain U.S. workers with the necessary skill sets
Erosion of U.S.-based infrastructure	Loss of specialized capital equipment needed to integrate, manufacture, or maintain capability
Product security	Lack of cyber and physical protection results in eroding integrity, confidence, and competitive advantage

Figure 23: Ten Risk Archetypes Threatening America's Manufacturing and Defense Industrial Base

The impacts identified by the working groups often fell into multiple risk archetypes – a financially distressed foundry may be both a sole source and single source, as well as illustrate a fragile market. In this section, we summarize illustrative examples from the working groups in each of the risk archetypes. Additional descriptions of the impacts can be found in the sector summaries (Appendix Two) and a full list of the nearly 300 impacts for all sixteen sectors is available in a classified appendix.

1. Sole Source

A sole source risk exists when only one supplier is able to provide the required capability. Sole source risk can occur at the prime level – such as one supplier capable of building nuclear aircraft carriers – but more often sole source manifests in the sub-tier of a sector.

Reduced competition, lack of innovation, and potential single points of failure in the production of chaff countermeasures underscore risks associated with a sole source. Chaff is composed of millions of tiny aluminum or zinc coated fibers stored on-board an aircraft in tubes. When an aircraft is threatened by radar tracking missiles, chaff ejected into the turbulent wake of air behind the plane creates confusion for the missile's radar system. Defense unique requirements and decreasing DoD demand drove out other suppliers, leaving one company as the only source for chaff.

Similarly, DoD acquisition policy modifications to meet demand and surge requirements from overseas operations have led to capacity issues within our organic arsenals. Due to policy

requirements, all large caliber gun barrels, howitzer barrels, and mortar tubes must be manufactured at a specific organic arsenal. Currently, there is only one production line that produces all these items, leading to a lack of capacity to meet current and near-term production demands.

2. Single Source

When only one supplier is qualified to provide a required capability, single source risk exists. The key distinction between sole source and single source is that for a single source, multiple potential vendors may exist, but only one source is qualified to produce materials for the U.S. Government.

Industries involved in the manufacturing of shipbuilding components were among the hardest hit by the global shift in the industrial base over the last 20 years. Of the top ten highest grossing industries in Navy shipbuilding, six are in the manufacturing sector. Since 2000, these industries experienced a combined decline of over 20,500 domestic establishments.** Contraction of the shipbuilding industrial base has limited competition among U.S. suppliers of Navy components and, in many cases, competition has altogether vanished, forcing the Navy to rely on single and sole source suppliers for critical components.

There currently exists only one domestic source of ammonium perchlorate – a chemical widely used in DoD propulsion systems. Foreign sources exists, but maintaining a domestic capability is critical to national security.

3. Fragile Supplier

A fragile supplier is an individual firm that is financially challenged or distressed.

Within the rotary wing industrial base, one company illustrates the interaction of single source risk and fragile supplier. The firm occupies a supply chain tier in the large and complex alloy castings segment of the aircraft sector, and is a source for upper, intermediate, and sump housing required for the manufacturing of a heavy lift platform for the Marines. In 2016, the company filed for bankruptcy, citing a decline in the military and commercial helicopter market.[127] Without a qualified source for these castings, the program will face delays, impeding the DoD's ability to field heavy lift support for Marine Corps expeditionary forces.

With the large movement of textile manufacturing to cheaper foreign markets, and fewer domestic companies producing textiles, soldier systems such as tents and uniforms face greater risk. Currently, only a few domestic sources can provide the specific material requirements for defense-specific textiles, especially for various types of highly engineered textile fibers (e.g.,

** The six industries are machinery; transportation equipment manufacturing; fabricated metal products; computer and electronic products; electrical equipment, appliance, and components.

high-tenacity polyester, nylon 6,6, etc.). During the course of the EO 13806 assessment, the single supplier for high-tenacity polyester fiber used in DoD tent systems dissolved its business. It was no longer able to compete in an increasingly competitive global fibers and textiles market, and now the U.S. lacks a manufacturing capability for high-tenacity polyester fiber that allows for military specification qualification.

4. Fragile Market

A fragile market occurs when domestic markets have structurally challenging economics and face a potential move toward foreign dependency. Fragile suppliers exist at the firm level, whereas fragile markets exist across an industry or sector.

Domestic printed circuit board manufacturing struggles to compete in the global marketplace. Since 2000, the U.S. has seen a 70% decline in its share of global production. Today, Asia produces 90% of worldwide printed circuit boards, and half that production occurs in China. As a result, only one of the top 20 worldwide printed circuit board manufacturers is U.S.-based. With the migration of advanced printed circuit board manufacturing offshore, DoD risks losing visibility into the manufacturing provenance of its electronics.

Also in the electronics sector, and ubiquitous in platforms and systems across the industrial base, strategic radiation-hardened microelectronics have no commercial applications. These components must be able to withstand short bursts of intense radiation and high temperatures in order to satisfy mission requirements. Being commercially unviable creates continual risk for this critical capability due to changing business conditions or technological obsolescence.

5. Capacity Constrained Supply Market

Capacity constrained supply markets arise where necessary capacity is unavailable in required quantities or time due to competing commercial market demands or insufficient defense specific capacity.

ASZM-TEDA1 impregnated carbon, a defense-unique material provided by a single qualified source, is subject to a single-point-of-failure and demonstrates a capacity constrained supply markets. A lack of competition with other potential sources precludes assurances for best quality and price. While ASZM-TEDA1 is used in 72 DoD chemical, biological, and nuclear filtration systems, the current sourcing arrangements cannot keep pace with demand.

The high operational tempo of the Navy in recent years, along with a lack of steady funding for maintenance and modernization, has resulted in a backlog of repair work across the nuclear and non-nuclear fleet. Coupled with increases in new ship construction, many suppliers are experiencing a shortfall in their capacity to perform work and manufacture products. The increased demand creates pressure on already-aging production equipment and could necessitate additional hiring in highly specialized fields, where it is often difficult to find suitable

candidates. Technical requirements for new ships, a large volume of mid-life availabilities, and a general lack of investment by industry in new dry-dock capacity will create a significant constraint for completing Navy ship maintenance. The combination of limited suppliers and an increase in workload could increase cost and potentially create schedule slips, impacting our Warfighting capability.

6. Foreign Dependency

Foreign dependency risk arises when domestic industry does not produce the item, or does not produce it in sufficient quantities. Not all foreign dependency is equal – the cases here illustrate dependency on both competitors and allies.

China is the single or sole supplier for a number of specialty chemicals used in munitions and missiles. In many cases, there is no other source or drop-in replacement material and even in cases where that option exists, the time and cost to test and qualify the new material can be prohibitive – especially for larger systems (hundreds of millions of dollars each).

Single foreign sources of unique and proprietary carbon fibers from Japan and Europe represent considerable DoD supply chain vulnerabilities. A sudden and catastrophic loss of supply would disrupt DoD missile, satellite, space launch, and other defense manufacturing programs. In many cases, there are no substitutes readily available. Replacing a carbon fiber factory is very expensive and time consuming. Of similar concern is the uncertainty of qualifying replacement suppliers and significant resource requirements.

U.S. military "night vision" systems are enabled by an image intensifier tube, a vacuum sealed tube that amplifies a low light-level scene to observable levels. The U.S. is reliant on a German supplier for the image intensifier tube core glass, a DoD-unique product with low demand compared to commercial glass production. While the German supplier manufactures the core glass in batches every few years to replenish a U.S. buffer stock, we still lack a domestic supplier, creating vulnerability in the night vision supply chain.

7. Diminishing Manufacturing Sources and Material Shortages

Diminishing manufacturing sources and material shortages risk is associated with obsolescence that may result from the decline in relevant suppliers.

In 2017, a semiconductor chip foundry used in a voltage control switch (used in all DoD missiles systems) was purchased by another foundry. A 5th tier supplier, the voltage control switch company notified its next tier customer of the foundry closing and received an end-of-life buy order for what was considered enough supply to allow time to qualify a replacement voltage control switch. DoD was not informed of the issue or consulted on the end-of-life quantity until the opportunity to stockpile had passed, at which point it became evident that the end-of-life buy, intended to last 3-5 years, would only last 6 months, putting U.S. missile systems at risk.

Trusted foundries, obsolescence, diminishing manufacturing sources and material shortages, and counterfeit issues are common to the broad defense electronics sector and prevalent for current and future radar systems, as well as systems in sustainment. One logistics center within the organic base identified over 4,000 diminishing manufacturing sources and material shortages items for just the radars maintained at that particular base. In addition to sustainment issues, the military is highly dependent upon the commercial sector for technology maturation, but the commercial sector is driven by revenue and high volume technology demands so development of technology for military use is not always feasible.

8. Gaps in U.S.-based Human Capital

When industry or the government is unable to hire or retain U.S. workers with the skills sets, or capabilities, needed to support the industrial base, gaps in U.S.-based human capital arise.

In December 2017, a survey of 662 manufacturing companies conducted by the National Association of Manufacturers found the inability to attract and retain a quality workforce the top business challenge, cited by 72.9% of respondents. To address this workforce challenge, 66% of respondents said they are increasing the workload of their existing employees. 34.4% stated their company had been unable to take on new business and had lost revenue opportunities because of the inability to attract and retain workers.[128] Given the number of manufacturers who exist in the supply chain of the industrial base, these numbers are significant.

The industrial base consistently competes with commercial industry for STEM talent, and the education pipeline is not providing the necessary resources to fully meet current or future demands in the commercial sector and defense ecosystem, such as software design engineers and biophysicists. In addition, the trade skills gap affects a wide range of occupations (e.g., industrial machinery mechanics and welders) which could have potentially significant impacts on production of critical defense-related materials, vehicles, and machinery, as well as other goods and services necessary to supply our nation's armed forces.

9. Erosion of U.S.-Based Infrastructure

The loss of specialized capital equipment needed to integrate, manufacture, or maintain a capability creates erosion of U.S.-based infrastructure.

A largely niche market, the chemical, biological, radiological, and nuclear sector relies heavily on DoD procurements for sustainability. One of the organic bases that provides chemical, biological, radiological, and nuclear technology lacks a sustainable workload, degrading readiness by creating a capabilities response lag time, increasing labor rates, and threatening critical manufacturing capabilities. Gaps in this sector can result in limited or non-existent domestic supply of critical protection for the Warfighter against specific threats.

Organic base depots are working capital funded activities and are required to reinvest and recapitalize equipment and facilities through their rate structure. While DoD's budget replaces and refurbishes plant equipment, and statute and policy direct follow-through on recapitalization, infrastructure investments have not been adequate often due to sensitivity to rate increases. Without significant future investment, the organic base will remain challenged by outdated equipment, tooling, and machinery. The erosion of organic infrastructure continues to impact turnaround time and repair costs of newly fielded weapon systems, reducing inventory, decreasing operational readiness, and impacting future deployment schedules.

10. Product Security

A lack of cyber and/or physical protection creates risk in product security, resulting in an erosion of integrity, confidence, and competitive advantage.

For example, one Chinese manufacturer accounts for 70% of the commercial unmanned aerial system market, including a dominance in the small unmanned aerial system subsector. Recently, due to concerns around security of the software associated with the platform, the U.S. Army issued a memo to cease use of applications created by the manufacturer.[129]

The defense manufacturing supply chain flows goods and critical supporting information through multiple organizations of varying size and sophistication to transform raw materials into components, subassemblies, and ultimately finished products and systems that meet DoD performance specifications and requirements. These supply chain operations rely on an infinite number of touch points where digital and physical information flows through multiple networks – both within and across many manufacturers' systems. In today's digitized world, every one of these supply chain touch points represents a potential product security risk.

According to private sector reports, in 2014 manufacturers received the greatest volume of targeted cyber-attacks of all industries globally,[130] primarily for espionage purposes,[131] although an increasing number of sophisticated cyber-espionage campaigns attempted to alter the automation of physical processes on manufacturing lines. The Department of Homeland Security reported in 2015 that the critical manufacturing sector reported the highest number of attacks on industrial control systems of any critical infrastructure sector, nearly twice the 2014 level. Since then, numerous threats have emerged with the potential to cause major disruption in manufacturing operations.

This page intentionally blank.

VII. A Blueprint for Action

President Trump's historic EO 13806 provided DoD and its interagency partners a unique opportunity to assess the manufacturing and defense industrial base – one of the most critical assets to our national security. The work conducted by the over 300 members of the DoD-led Interagency Task Force lays the groundwork for important actions, mitigations, and ongoing monitoring that will result in America's ability to continue supporting a secure, robust, resilient, and ready industrial base.

Current Efforts

The DoD-led Interagency Task Force recognizes and supports ongoing efforts to address the challenges identified in the EO 13806 assessment, including:

- Increased near-term DoD budget stability with the passage of the Bipartisan Budget Act of 2018, providing stable funding through FY2019
- Modernization of the Committee on Foreign Investment in the U.S. and investigations under Section 301 of the Trade Act of 1974 into Chinese intellectual property theft, to better combat Chinese industrial policies targeting American intellectual property
- Updates to the Conventional Arms Transfer policy and unmanned aerial systems export policy to increase U.S. industrial base competitiveness and strengthen international alliances

- Reorganization of the former Office of the Under Secretary of Defense for Acquisition, Technology and Logistics, the work of the "Section 809 panel," and development of the adaptive acquisition framework all aim to streamline and improve defense acquisition processes
- Restructuring the Defense Acquisition University to create workforce education and training resources that will foster increased agility in acquisition personnel
- Response to Section 1071(a) of the National Defense Authorization Act for FY2018 which requires establishing a process for enhancing the ability to analyze, assess, and monitor vulnerabilities of the industrial base
- Creation of a National Advanced Manufacturing Strategy by the White House Office of Science and Technology Policy, focused on opportunities in advanced manufacturing
- Department of Labor's chairing of a Task Force on Apprenticeship Expansion to identify strategies and proposals to promote apprenticeships, particularly in industries where they are insufficient
- DoD's program for Microelectronics Innovation for National Security and Economic Competitiveness to increase domestic capabilities and enhance technology adoption
- DoD's cross-functional team for maintaining technology advantage
- Implementation of a risk-based methodology for oversight of contractors in the National Industrial Security Program, founded on risk management framework principles to assess and counter threats to critical technologies and priority assets

Future Efforts and Recommendations

The Secretary of Defense strongly recommends the President sign an Executive Order directing DoD, and the Secretaries listed below, to promptly implement the proposed recommendations based on the EO 13806 assessment, submitted herein. Of the nearly 300 risks identified by the working groups across 16 sectors, the recommendations provided below and in the classified Action Plan address risks determined to currently be of critical importance, and propose actionable and reasonable mitigations. Each of the Secretaries will provide a status on implementation within 180 days of execution of the Executive Order.

Secretary of Defense

DoD recommendations are provided below and in a classified Action Plan. The recommendations include:

- Create an industrial policy in support of national security efforts, as outlined in the National Defense Strategy, to inform current and future acquisition practices
- Expand direct investment in the lower tier of the industrial base through DoD's Defense Production Act Title III, Manufacturing Technology, and Industrial Base Analysis and Sustainment programs to address critical bottlenecks, support fragile suppliers, and mitigate single points-of-failure

- Diversify away from complete dependency on sources of supply in politically unstable countries who may cut off U.S. access; diversification strategies may include reengineering, expanded use of the National Defense Stockpile program, or qualification of new suppliers
- Work with allies and partners on joint industrial base challenges through the National Technology Industrial Base and similar structures
- Modernize the organic industrial base to ensure its readiness to sustain fleets and meet contingency surge requirements
- Accelerate workforce development efforts to grow domestic STEM and critical trade skills
- Reduce the personnel security clearance backlog through more efficient processes
- Further enhance efforts exploring next generation technology for future threats

Secretary of Energy

- Submit legislative proposal for FY2020 to establish an Industrial Base Analysis and Sustainment program to address manufacturing and industrial base risk within the energy and nuclear sectors.

Secretary of Labor

- Work with the Departments of Defense, Education, and Commerce to determine critical manufacturing and defense industrial base occupations and their corresponding definitions in the 2018 Standard Occupational Classification System. Using historical data from the Bureau of Labor Statistics and demand data gathered from industry, determine specific occupations to target for current and future pipeline growth (e.g. systems engineers, computer numerically controlled tool operators, welders) and:
  - Assess potential incentives to recruit and retain workers to enter and/or stay in the industrial base, such as tuition reimbursement.
  - Create or foster comprehensive training and education programs in coordination with federal, state, academic, and local sponsors.
- Work with states to reduce occupational licensing barriers preventing qualified workers from quickly and efficiently meeting needs in other regions, thereby aiding geographic movement of individuals possessing critical skills to areas in need of human capital for production and maintenance (e.g. shipyards, depots, and production plants).

This page intentionally blank.

APPENDICES

This page intentionally blank.

Appendix One: Executive Order 13806

ASSESSING AND STRENGTHENING THE MANUFACTURING AND DEFENSE INDUSTRIAL BASE AND SUPPLY CHAIN RESILIENCY OF THE UNITED STATES

By the authority vested in me as President by the Constitution and the laws of the United States of America, it is hereby ordered as follows:

Section 1. Policy. A healthy manufacturing and defense industrial base and resilient supply chains are essential to the economic strength and national security of the United States. The ability of the United States to maintain readiness, and to surge in response to an emergency, directly relates to the capacity, capabilities, and resiliency of our manufacturing and defense industrial base and supply chains. Modern supply chains, however, are often long and the ability of the United States to manufacture or obtain goods critical to national security could be hampered by an inability to obtain various essential components, which themselves may not be directly related to national security. Thus, the United States must maintain a manufacturing and defense industrial base and supply chains capable of manufacturing or supplying those items.

The loss of more than 60,000 American factories, key companies, and almost 5 million manufacturing jobs since 2000 threatens to undermine the capacity and capabilities of United States manufacturers to meet national defense requirements and raises concerns about the health

of the manufacturing and defense industrial base. The loss of additional companies, factories, or elements of supply chains could impair domestic capacity to create, maintain, protect, expand, or restore capabilities essential for national security.

As the manufacturing capacity and defense industrial base of the United States have been weakened by the loss of factories and manufacturing jobs, so too have workforce skills important to national defense. This creates a need for strategic and swift action in creating education and workforce development programs and policies that support job growth in manufacturing and the defense industrial base.

Strategic support for a vibrant domestic manufacturing sector, a vibrant defense industrial base, and resilient supply chains is therefore a significant national priority. A comprehensive evaluation of the defense industrial base and supply chains, with input from multiple executive departments and agencies (agencies), will provide a necessary assessment of our current strengths and weaknesses.

Sec. 2. Assessment of the Manufacturing Capacity, Defense Industrial Base, and Supply Chain Resiliency of the United States. Within 270 days of the date of this order, the Secretary of Defense, in coordination with the Secretaries of Commerce, Labor, Energy, and Homeland Security, and in consultation with the Secretaries of the Interior and Health and Human Services, the Director of the Office of Management and Budget, the Director of National Intelligence, the Assistant to the President for National Security Affairs, the Assistant to the President for Economic Policy, the Director of the Office of Trade and Manufacturing Policy, and the heads of such other agencies as the Secretary of Defense deems appropriate, shall provide to the President an unclassified report, with a classified annex as needed, that builds on current assessment and evaluation activities, and:

(a) identifies the military and civilian materiel, raw materials, and other goods that are essential to national security;

(b) identifies the manufacturing capabilities essential to producing the goods identified pursuant to subsection (a) of this section, including emerging capabilities;

(c) identifies the defense, intelligence, homeland, economic, natural, geopolitical, or other contingencies that may disrupt, strain, compromise, or eliminate the supply chains of goods identified pursuant to subsection (a) of this section (including as a result of the elimination of, or failure to develop domestically, the capabilities identified pursuant to subsection (b) of this section) and that are sufficiently likely to arise so as to require reasonable preparation for their occurrence;

(d) assesses the resiliency and capacity of the manufacturing and defense industrial base and supply chains of the United States to support national security needs upon the occurrence of the contingencies identified pursuant to subsection (c) of this section, including an assessment of:

(i) the manufacturing capacity of the United States and the physical plant capacity of the defense industrial base, including their ability to modernize to meet future needs;

(ii) gaps in national-security-related domestic manufacturing capabilities, including non-existent, extinct, threatened, and single-point-of-failure capabilities;

(iii) supply chains with single points of failure or limited resiliency, especially at suppliers third-tier and lower;

(iv) energy consumption and opportunities to increase resiliency through better energy management;

(v) current domestic education and manufacturing workforce skills;

(vi) exclusive or dominant supply of the goods (or components thereof) identified pursuant to subsection (a) of this section by or through nations that are or are likely to become unfriendly or unstable; and

(vii) the availability of substitutes for or alternative sources for the goods identified pursuant to subsection (a) of this section;

(e) identifies the causes of any aspect of the defense industrial base or national- security-related supply chains assessed as deficient pursuant to subsection (d) of this section; and

(f) recommends such legislative, regulatory, and policy changes and other actions by the President or the heads of agencies as they deem appropriate based upon a reasoned assessment that the benefits outweigh the costs (broadly defined to include any economic, strategic, and national security benefits or costs) over the short, medium, and long run to:

(i) avoid, or prepare for, any contingencies identified pursuant to subsection (c) of this section;

(ii) ameliorate any aspect of the defense industrial base or national-security- related supply chains assessed as deficient pursuant to subsection (d) of this section; and

(iii) strengthen the United States manufacturing capacity and defense industrial base and increase the resiliency of supply chains critical to national security.

Sec. 3. General Provisions. (a) Nothing in this order shall be construed to impair or otherwise affect:

(i) the authority granted by law to an executive department or agency, or the head thereof; or

(ii) the functions of the Director of the Office of Management and Budget relating to budgetary, administrative, or legislative proposals.

(b) This order shall be implemented consistent with applicable law and subject to the availability of appropriations.

(c) This order is not intended to, and does not, create any right or benefit, substantive or procedural, enforceable at law or in equity by any party against the United States, its departments, agencies, or entities, its officers, employees, or agents, or any other person.

DONALD J. TRUMP

THE WHITE HOUSE,

July 21, 2017.

This page intentionally blank.

Appendix Two: Sector Summaries

Each of the working groups provided a summary of their respective sector in the following pages, including explanations of impacts the risk archetypes have on their sector's ability to support national security. The sector summaries focus on prime suppliers; information regarding risk below the prime tier is available for some sectors in the classified annex.

Traditional Defense Sectors

Aircraft Sector

Aircraft includes fixed wing, rotorcraft, and unmanned aerial systems required for air-to-air and air-to-ground military operations and transport. Fixed wing aircraft include fighters, bombers, cargo, transportation, and any manned aircraft that use a set of stationary wings to generate lift and fly. DoD rotorcraft operate in harsh battlefield environments, requiring robust, advanced capabilities and systems. Unmanned aerial systems include the necessary components, equipment, network, and personnel to control an unmanned aircraft; in some cases, unmanned aerial systems also include a launching element.

While large airframes and subsystems rely heavily on commercial technologies, processes, and products, defense-unique design and manufacturing skills are needed to meet the requirements of military weapon systems, produce next-generation aircraft, and maintain technological advantage. Six companies provide the majority of aircraft platforms and possess the full range of capabilities to bring a new weapon system from the research, design, and development phases into full production.

The rotorcraft industry consists of two major segments: defense and commercial. The mission and capability requirements between the two segments are substantially different. While military rotary wing funding peaked in 2011 and has since declined by over 40%, it is projected to increase again due to programs including Future Vertical Lift. The funding levels for the last decade have been historically high due to the high operational tempo and utilization in theater.

Diverse and complex, the unmanned aerial systems industry ranges from bird-size (classified as Group I) to 100+ foot wingspans (Group V) and includes both unmanned and manned-with-autonomy. The industry supporting unmanned aerial system production is wide-ranging and in a state of rapid transition, as civil end-users overtake military-specific users, with a significant shift in market development and production of small to medium-sized platforms (Groups I-III)

from U.S. sources to those based in China. As current conflicts wind down, there will be a reduction in planned military buys and more focus on evolving systems that can survive in an Anti-Access Areal Denial or defended airspace.

All three aircraft sub-sectors face challenges, including long product/system development timelines, high development and qualification costs, and production limitations. During the 1990s, a dramatic decline in aircraft procurement led to consolidation of prime suppliers in the sector. Consolidation continues today and has expanded into the sub-tiers of the supply chain, creating additional risks for single or sole source vendors. In addition, the sector is experiencing a shortage of workers with critical hardware and software design capabilities due to large retirement populations, limited platform knowledge transfer opportunities, and skyrocketing demand for software engineers outstripping supply in multiple product line sectors.

Case Studies: Aircraft Sector Impacts on National Security

Gaps in the aircraft sector directly reduce domestic capability to produce and field a fleet capable of providing superior offensive and defensive capabilities against adversaries. The case studies included below illustrate how trends in workforce, industry consolidation, and individual company risk impact the quality and quantity of U.S. military aircraft.

Aircraft Design and Engineering Human Capital

Defense-unique design skills are required to spur innovation and enable revolutionary platform development. Current modernization programs help sustain important capabilities but do not provide enough opportunities to maintain skills to dominate major design and next generation development work. With the approaching end of several advanced development programs, an absence of new requirements in the next five to seven years, and increasing numbers of retirees with critical experience, the industrial base workforce faces a shortage of critical design capabilities. Maintaining innovation becomes nearly impossible while facing the constant threat of skilled aerospace, mechanical, electrical, and software engineers leaving the workforce and not passing along critical knowledge of next-generation technologies and fifth/sixth generation enabling capabilities to new employees. Another endemic workforce weakness experienced across much of the aircraft sector is the original equipment manufacturers' inability to maintain innovation and design skill development due to a lack of consistent R&D funds.

Each subsector faces distinct challenges. In the fixed wing sector, keeping design teams active for next generation tactical air support fighters may become an issue because industry will not see a new program starts until the F-X and F/A-XX programs begin to take shape. Compounding this issue, most current tactical air support design engineering teams have employees at or near retirement age. Industry is working closely with the Defense Advanced Research Projects Agency on the Penetrating Counter Air and Next Generation Air

Dominance programs, efforts that will set the stage for next generation fighter aircraft capabilities and survivability and provide current teams with new design work, through which older employees can transfer unique skills and knowledge to the next generation.

Impacts of Limited Innovation

Without design competition, DoD will see limited innovation, increased cost, and additional time added to new starts. Production capacity could also become a concern as legacy programs end (F-15, F-16, & F-18) and production lines close. The facilities where these lines are located will likely be refitted for other purposes and space will be occupied with new workload or closed. If this occurs, it will have a limiting effect on industry's ability to surge production in the future. In rotorcraft, twelve legacy platforms are currently in production or sustainment and three are in engineering, manufacturing, and development. There have been no clean sheet program starts through production since 1983. As decisions on the Future Vertical Lift program are delayed, industry design teams and other industrial capabilities could be at risk. In unmanned aerial systems, only the MQ-25 is in engineering, manufacturing, and development, with limited public new design on the horizon. As time goes on, design teams could be in jeopardy, with domestic producers of smaller class unmanned aerial systems experiencing a shrinking market share.

Large, Complex Alloy Castings

There are currently four suppliers with the capability to manufacture large, complex, single pour aluminum and magnesium sand castings. These suppliers face perpetual financial risk and experience bankruptcy threats and mergers mirroring the cyclicality of DoD acquisition. The single qualified source for the upper, intermediate, and sump housing for a heavy lift platform for the Marines has experienced quality issues and recently went through bankruptcy proceedings. Without a qualified source for these castings, the program will face delays, impeding the U.S. ability to field heavy lift support to Marine Corps expeditionary forces.

Chemical, Biological, Radiological, and Nuclear Sector

Chemical, biological, radiological, and nuclear encompasses capabilities through science, engineering, testing, and logistics to create products that provide protection from threats and attacks.

The DoD Chemical and Biological Defense Program's mission is to enable the Warfighter and first responders to deter, prevent, protect, mitigate, respond, and recover from chemical, biological, radiological, and nuclear threats and effects as part of a layered, integrated defense. To support this mission, the Chemical and Biological Defense Program industrial base sustains the capabilities needed to support the three strategic readiness goals: 1) equip the force to successfully conduct military operations to prevent, protect, and respond to chemical, biological, radiological, and nuclear threats and effects; 2) develop new capabilities to counter emerging chemical, biological, radiological, and nuclear threats; and 3) maintain industrial capabilities in the form of workforce, infrastructure, testing, R&D, and manufacturing to achieve current and future National Security Strategy requirements.

The sector is composed of commercial and organic industry of all sizes to meet the Chemical and Biological Defense Program mission. It is also a niche market heavily dependent upon DoD procurements for sustainability and defined by the engineering, testing, logistics, and production capabilities to meet the following technical areas: medical countermeasures to address chemical, biological, radiological, and nuclear and emerging infectious diseases and threats through vaccines and antidote treatments; protection for the Warfighter through respirators, masks, decontamination kits, etc.; contamination avoidance through development and use of sensors, monitors, and detectors; guardian systems to provide support for first responders; and information systems that consist of integrated early warning, hazard prediction models, consequence management, and decision support tools. The 2017 National Security Strategy indicates the importance of the sector as it provides critical capabilities to counter

hostile states and terrorist groups increasingly trying to acquire nuclear, chemical, radiological, and biological weapons.

Case Studies: CBRN Sector Impacts on National Security

The case studies below illustrate how a capacity-constrained supply market, structurally poor industry economics, and the erosion of U.S.-based infrastructure create gaps in the sector that may lead to limited or non-existent domestic supply of capabilities to protect the Warfighter against current and future threats.

ASZM-TEDA1

ASZM-TEDA1 impregnated carbon is a defense-unique material provided by a single qualified source, subject to a single-point-of-failure. A lack of competition with other potential sources precludes assurances for best quality and price. While ASZM-TEDA1 is used in 72 DoD chemical, biological, and nuclear filtration systems, the current sourcing arrangements cannot keep pace with demand. DoD is using Defense Production Act Title III authorities to establish an additional source of this critical material.

Organic Base Arsenal

Inconsistent workload and future projections degrade the ability to sustain current capabilities and to develop capabilities for future requirements at an organic arsenal in support of Joint Forces readiness requirements. The difficulty in providing a sustainable workload to this organic production base negatively impacts the ability to retain and develop human capital, increases overhead costs, and limits the ability to surge or respond quickly to Chemical and Biological Defense Program requirements. In addition, the sustainment of the production facility in providing low volume legacy components and end items is vital.

Ground Systems Sector

Ground systems provide defense unique products for mobility and firepower, and are divided into tracked and wheeled vehicles for combat, combat support, and combat service support.

The ground systems sector is defined by a small set of prime suppliers engaged solely in production for both tracked and wheeled vehicles. There are two main suppliers for tracked tactical vehicles – one supplier specializing in steel fighting vehicles and another specializing mostly in aluminum armored vehicles. Wheeled combat service support vehicles are considered a defense-unique product, but the industrial base supporting this subsector is highly dependent on commercial automotive technology and production capabilities. Two domestic suppliers dominate tactical wheeled vehicle manufacture, but there are multiple qualified vendors for the repair, refurbishment, and modifications business.

There are only a few active programs within various development phases for legacy systems in the tracked vehicles subsector, including armored multi-purpose vehicles; amphibious assault vehicles; M1A1/ M1A2 vehicles; M109 vehicles; and armored tank retriever variants. The ground systems sector followed a strategy of incremental adoption of new technologies on legacy designs to maintain or modify current ground systems, allowing the military to defer the long schedules and high costs of new programs. However, this resulted in a generation of engineers and scientists that lack experience in conceiving, designing, and constructing new, technologically advanced combat vehicles.

Many current wheeled tactical vehicle fleets are in the middle of their lifecycles, which are generally planned for 20 years with a rebuild at the ten year mark, but this can vary with utilization. The existing vehicle fleets are healthy, as increased production has lowered the average age of the platforms, and Overseas Contingency Operations maintenance funding allowed for rebuilds and modifications to be applied at the same time. Advances in technology

and engineering innovation led to improvements in existing equipment, prolonging vehicle service life and increasing the capability of legacy vehicles.

Opportunities for new work, modernization, and recapitalization are important to keep prime suppliers competitive. The Army is preparing two programs that will provide much needed work to exercise design skills in the wheeled vehicle industrial base: 1) development of a replacement medium tactical vehicle; and 2) the Mobile Protected Firepower to design and field a more lethal armored fighting vehicle.

Fragility exists in the sector for systems with long lifecycles and equipment not used in ongoing combat operations or training. As a result, a lack of steady orders for vehicles leads prime vendors and their suppliers to reduce excess capacity in labor and facilities, leaving the ground systems sector at risk of not meeting service and combatant command requirements for modern, new, and additional equipment that can dominate the battlefield. Industrial facilities are not readily available to produce, the workforce is limited, and competition for common supply chain products and other materials would require prioritization across the ground vehicle supply chain as well as across services.

Case Studies: Ground Vehicle Sector Impacts on National Security

The following case studies illustrate how gaps in the ground vehicle sector directly reduce capabilities to maintain a forward military presence needed to deter and defeat any adversary, and adapt to new strategies and techniques of battle.

Wrought Aluminum Plate Production Capacity

Wrought aluminum plate, and specifically cold-rolled plate, is essential for armoring U.S. ground combat vehicles, constructing Navy ships, and building military aircraft. Unlike other more common forms of rolled aluminum materials, thick cold-rolled aluminum production capabilities and capacities are unique. DoD relies on domestic producers as well as capabilities available from ally countries in Europe. Due to U.S. Government budget uncertainties, unpredictable DoD demand, and other commercial market factors, the defense industrial base can face challenges when trying to balance diverse demands for cold-rolled plate production capacity while also informing long-term internal capital investment decisions. Other challenges facing the domestic industrial base include the effects of foreign competition. Under certain circumstances, the defense industrial base could potentially face production bottlenecks during a future surge in DoD requirements.

Manufacture of Gun Barrels, Howitzer Barrels, and Mortar Tubes

Legislation and DoD industrial policy requires DoD to manufacture all large caliber gun barrels, howitzer barrels, and mortar tubes at one organic DoD arsenal. There is only one production line at the arsenal for all of these items, and policy modifications to meet demand

and surge from overseas have led to a lack of capacity to meet current production requirements.

Capacity Shortfall for Future Armored Brigade Combat Team Goals

Over 80% of Army and Marine Corps combat vehicle production consolidated to one manufacturer at one assembly facility. Almost none of these vehicles have ever been completely manufactured at this facility. None have been manufactured simultaneously and the facilities capacity to support simultaneous manufacture is currently under examination.

Munitions and Missiles Sector

Munitions include 'dumb' bombs, ammunition, mortars, and tank rounds, etc., and missiles include 'smart' bombs, tactical (air-to-air, air-to-ground, surface-to-air, cruise) missiles, missile defense, and strategic missiles. The sector is primarily defense-unique and is subject to wartime needs – procurement ramps up during wartime and reduces when conflict ends. The market is defined by this conflict-reliant pattern, creating significant management and viability challenges for suppliers and their sub-tiers.

The missile sector has undergone significant consolidation in the past several decades. Two of the five prime contractors account for roughly 97% of DoD's missile procurement funding. As of the writing of this report, one of the prime contractors is attempting to acquire another prime. There are currently only two domestic suppliers for solid rocket motors used in the majority of DoD missile systems, with a single foreign supplier making up the balance.

Over the past two decades, DoD has fielded no completely new tactical missile designs. New programs have been upgrades to existing systems, but there have been no solid rocket motor improvements. The sector is also suffering a post-drawdown decline in procurement, resulting in loss of critical design and production skills. However, two new tactical missile programs are

entering development and, if they continue, will provide needed work to exercise the tactical missile industrial base design skills – the Advanced Anti-Radiation Guided Missile Extended Range and Long Range Precision Fires. There is also one new strategic missile program, Ground Based Strategic Deterrent, the LGM-30G Minute Man III Inter-Continental Ballistic Missile replacement. Numerous demonstration and validation programs have been funded over the past several years by the Ground Based Strategic Deterrent program, providing some design work to industry, particularly to the large solid rocket motor industrial base.

The ammunition and munitions base is critical to the life cycle management of more than 650 programs, over 1,200 end items, and over 1,300 components. Efficiencies in contracting and cost effectiveness have been gained with the Army as the Single Manager for Conventional Ammunition for all Services, including procurement from both organic and private sector suppliers. Private sector suppliers, the majority of which are domestic, are of crucial importance to conventional munitions production – which does not include missiles. Historically, 70-75% of procurement funding for munitions has been directed toward the private sector.

Case Studies: Munitions and Missiles Sector Impacts on National Security

Gaps in munitions and missiles directly reduce the U.S. capability to deliver kinetic effects against adversaries. The case studies below illustrate how risks have hampered U.S. mission goals in recent years, as well as the impact to immediate and long term U.S. wartime capabilities.

Silicon Power Switch

In 2017, the issue with the most impact was the obsolescence of a voltage controlled switch from a sub-tier supplier. The switch is used in electronic safe and arm devices, electronic ignition devices, and flight termination systems for all DoD missiles. The semiconductor chip foundry used in the voltage control switch was purchased by another foundry. A 5th tier supplier, the voltage control switch company notified their next tier customer of the foundry closing and received an end-of-life buy order for what was considered enough supply to allow time to qualify a replacement voltage control switch. DoD was not informed of the issue or consulted on the end-of-life quantity until two years after the event occurred. At that point, it became evident that the end-of-life buy, which was supposed to last 3-5 years, would only last 6 months. This left insufficient time to develop, test, integrate, and qualify the new switch before the old switches were depleted. Until new switches are qualified, affected DoD missile systems are at risk.

Advanced Medium Range Air-to-Air Missiles (AMRAAM)

After years of production, the supplier of the solid rocket motor for the Advanced Medium Range Air-to-Air missile encountered technical production issues. Subject matter experts from the government and industry were unable to determine the cause, leading to a

temporary work stop and potential loss for a critical solid rocket motor supplier. To keep the Advanced Medium Range Air-to-Air missile production line moving, the prime contractor for the missile pursued an alternative source for the solid rocket motor, and selected a Norwegian company to produce a new solid rocket for the missile.

Explosives Demand at Holston Army Ammunition Plant (HSAAP)

A government-owned, contractor operated facility is the only domestic source for most DoD explosives, and it can only produce 9 million pounds of a key DoD explosive per year. In early FY 2016, demand for this explosive for bomb fills abruptly increased to levels not seen in decades and the facility did not have sufficient capacity to meet demand. Foreign sources were not able to materially mitigate the capacity shortfall. A study determined that the facility's capacity would continue to be stressed for the foreseeable future, so a mitigation plan to increase capacity is being implemented at a cost of $500 million and with an estimated completion date of 2023.

Nuclear Matter Warheads Sector

The U.S. nuclear deterrent is a lynchpin in our defense planning and that of our allies and adversaries. Nuclear weapons are designed and produced to meet an "Always/Never" standard:

1. They must always work when authorized by proper authority, and
2. They must never work in any situation or environment (normal, abnormal, or adversarial) without authorization by proper authority.

Supply chain availability and integrity is crucial to achieving the "Always/Never" standard, but an increasing set of risks threaten the integrity of the enterprise. A summary is provided below, while a classified version of this report provides further details.

Major Risks: Nuclear Matter Warheads Sector

Skilled, Clearable Workforce

The U.S. faces a diminishing supply of clearable labor with the advanced education and training necessary for designing, producing, and stewarding nuclear weapons. The primary source of that labor, U.S. colleges and universities, generate insufficient U.S. citizen graduates in the STEM areas relevant to the nuclear enterprise. The U.S. also lacks labor with important trade skills, including welders. Additional challenges due to clearance requirements greatly reduce the available pool of labor.

Microelectronics/Electronic Components

Nuclear warheads depend on trusted sources of microelectronics and electronics. Because the supply chain is globalized and complex, it is challenging to ensure that finished assemblies, subsystems, and systems exclusively leverage trusted, discrete components due to diminishing U.S.-based microelectronic and electronic manufacturing capability.

Critical Materials

Various sole source materials, addressed through the Nuclear Posture Review, are unavailable through trusted sources in sufficient quantities to ensure a robust and independent nuclear capability throughout the weapons lifecycle. The problem is exacerbated by policies and requirements that either limit or place restrictions on procurement options, e.g., life of program buys.

Software Systems/Applications

Lack of trusted sources of software design tools, data management systems, manufacturing execution, and facility controls introduce risk to the nuclear weapons engineering environment. This problem is exacerbated by poor cybersecurity practices by many key software vendors.

Analytical and Test Equipment

Given current nuclear weapons test restrictions, specialized analytical and test equipment is essential to ensure the "Always/Never" standard of nuclear weapon performance. Components, subsystems, and systems must be tested to unique qualification standards, but the supplier base for certain test equipment is increasingly globalized and not trusted, leading to uncertainty in testing.

Radar and Electronic Warfare Sector

Military radars and electronic warfare systems play a significant role in meeting our national security objectives. Radar is essential to detecting the presence, direction, distance, and speed of targets such as aircraft, ships, and weapons, and for controlling flight and weaponry. Detection is achieved by transmitting electromagnetic waves that are then reflected off objects and return back to the receiver. Required to operate in the harshest environments in order to support combat operations, military radar system requirements are often more stringent than those imposed on commercial systems. Radar systems have many applications and can even be used to detect slight changes to surfaces over time – allowing such capability as detection of footprints of shallow depth. Recent technological advances have enabled the rise of the Synthetic Aperture Radar, which leverages signal data processing to integrate radar returns over time as a radar system moves, and is used for search and rescue, target search/acquisition/identification/tracking, and weapons engagement. Synthetic Aperture Radar capabilities have become a game changer for state of the art and next generation radar systems and platforms.

Electronic warfare systems continue to become a more integral element of military weapon systems. Electronic warfare refers to military action involving the use of electromagnetic energy and directed energy to control the electromagnetic spectrum or to attack the enemy. The purpose is to deny the opponent the advantage of, and ensure friendly unimpeded access to, the electromagnetic spectrum; it includes capabilities for electronic attack, electronic support, and electronic protection. The systems are dependent upon technologies similar to those found in radar systems, including receivers and transmitters, and include countermeasure technologies such as chaff and flares that can target humans, communications, radar, or other assets.

DoD has roughly 100 radar systems in development, production, or sustainment with a similar portfolio of electronic warfare systems. These systems perform functions in four operational domains; land, air, space and sea and provide critical mission capabilities. There are a total of

23 firms that produce or have produced radars for DoD. Three domestic suppliers dominate the domestic radar market and four domestic suppliers dominate electronic warfare systems.

Case Studies: Radar and Electronic Warfare Sector Impacts on National Security

Gaps in the radar and electronic warfare sector directly reduce American capability to detect, find, fix, acquire, track, and attack threat systems in the face of an ever increasingly complex digitally driven environment. The case studies illustrate areas on which the U.S. needs to avoid becoming out matched in a current or next generation warfare scenario, where we would rely on radar and electronic warfare systems as key enablers to ensure survivability and dominance in a multi-domain battle space.

Radar and Electronic Warfare Software Developers & Engineering Shortages

Of greatest concern in this sector is prime contractors' ability to attract and retain the necessary software developers and engineers to develop and sustain radar and electronic warfare systems. Traditional radar and electronic warfare systems are minimally automated, requiring an operator to manually configure the system to operate in static modes. As the operational environment continues to grow in complexity with regards to the types and number of targets, and as commercial and military spectrum usage increases, our systems are forced to be cognitive, agile, automated, and multi-purposed. As the commercial sector and adversaries field similar capabilities, U.S. forces encounter systems that can "hide in the noise" and frequency hop to avoid detection and characterization.

To attack, defend, and counter against an increasingly complex and networked threat scenario, we must have a robust, capable, and agile workforce to update and modernize our military systems in critical technologies such as radio frequency solid state, power, high speed data interconnects and networks, software, and algorithms. Decreasing numbers in domestic software systems engineers, developers, and design engineers force defense suppliers to compete for talent with each other and with non-defense industries. Recruitment, training, and retention become key employer capabilities to ensure companies have the manpower to conduct R&D, design, modernization, and system upgrades within tactically relevant timelines. Without the appropriate depth of skilled engineers, America's leading edge in hardware architectures and software/firmware coding will continue to erode.

Electronic, Microelectronic, and Material Issues

Trusted foundries, obsolescence, diminishing manufacturing sources and material shortages, and counterfeit issues are common to the broad defense electronics sector. These issues are prevalent for current and future radar and electronic warfare systems as well as systems in sustainment. One logistics center within the organic base identified over 4,000 diminishing manufacturing sources and material shortages items for just the radars maintained at that

particular base. In addition to sustainment issues, the military is highly dependent upon the commercial sector for technology maturation, but the commercial sector is driven by revenue and high volume technology demands. In the microwave tube industry, DoD has only two primary microwave tube sources because of the commercial sector's migration to solid state technologies, creating a fragile market. Additionally, technology performance requirements being driven by the general public do not always lead to the development of technology that is feasible for military use. Given the fluidity of the commercial sector, the U.S.'s ability to lead advancements and retain long-term support infrastructure to support defense-specific electronics and microelectronics technologies areas will continued to be stressed.

Chaff and Flare Issues

Of concern is the limited number of U.S. based sources for chaff and flare countermeasures – both integral for defensive capabilities. Chaff is composed of millions of tiny aluminum or zinc coated fibers stored on-board the aircraft in tubes. When an aircraft is threatened by radar tracking missiles, chaff ejected into the turbulent wake of air behind the plane creates confusion for the missile's radar system. Defense unique requirements and decreasing DoD demand drove out other suppliers, leaving a single qualified source for chaff.

Flares distract heat-seeking missiles by ejecting hot magnesium pellets from tubes to ignite in the wake behind an aircraft. They burn at temperatures above 2,000 degrees Fahrenheit, hotter than the jet engine nozzles or exhaust, and exhibit large amounts of infrared light. Over the past decade, capacity in the flare industry has declined and DoD demand has dropped, leaving two domestic suppliers with little incentive to invest in infrastructure. Recently, the two domestic suppliers both experienced explosive accidents at their production sites and the subsequent shutdowns limited DoD program offices' ability to acquire products on time. Both companies have experienced quality and delivery problems since the accidents. As program offices look to improve quality and cost, they are beginning to look offshore at more modern facilities, where there are fewer quality and safety concerns.

Reduced Competition and Innovation

The military faces risk of reduced competition and innovation for fighter aircraft tactical active electronically scanned array radar systems. While there are other suppliers who have the capability to develop and produce these systems, there are only two domestic suppliers who have the unique engineering and design requirements and capabilities for size, weight, operational environment, and power associated with a tactical fighter aircraft. While similar active electronic scanned array systems are being produced for other applications, once the F/A-18 production ends (roughly 2024), only a single qualified source of the systems will remain.

Shipbuilding Sector

Shipbuilding includes the industrial base required to construct and maintain Navy aircraft carriers, submarines, surface ships, and their associated weapons and command and control systems.

The shipbuilding sector consists primarily of seven shipyards owned by four companies and their suppliers. Shipyards are fixed facilities with dry-docks and fabrication equipment that support ship construction, repair, conversion and alteration, and the production of refabricated ship sections and other specialized services. The sector also includes manufacturing and other facilities beyond the shipyard, which provide parts and services for shipbuilding activities. The industrial base supporting shipbuilding is segmented by ship type: aircraft carriers, submarines, surface combatants, amphibious warfare, combat logistics force, and command and support vehicles.

Over the last 60 years, Navy procurement profiles have shown sharp peaks in shipbuilding followed by significant breaks or valleys in production, severely degrading the ability of shipyards to conduct long-term planning and respond to near-term changes in requirements. This created a boom and bust within the industry, degrading the industrial base and resulting in longer construction times and increased costs. The steady, sustainable baseline shipbuilding profiles in the Annual Long-Range Plan for Construction of Naval Vessels for FY 2019 will establish industrial efficiency and agility, and protect workforce skills, in order for the U.S. shipbuilding industrial base to remain cost effective and meet the demands of the 355 ship Navy required for national defense.

Case Studies: Shipbuilding Sector Impacts on National Security

The shipbuilding industrial base is a national asset and absolutely vital to America's ability to build and sustain the Naval fleet. The Navy is focused on improving the health of the industrial base to meet its requirement of a 355 ship fleet with a long range plan anchored by industrial stability. The analysis performed in response to EO 13806 identified five underlying risks: dependency on single/sole source suppliers, capacity shortfalls, lack of competition, lack of workforce skills, and unstable demand.

Dependency on Single/Sole Source Suppliers

Industries involved in the manufacturing of shipbuilding components were among the hardest hit by the global shift in the industrial base over the last 20 years. Of the top ten highest grossing industries in Navy shipbuilding, six are in the manufacturing sector. Since 2000, these industries experienced a combined decline of over 20,500 establishments[††] in the U.S. Contraction of the industrial base has limited competition among U.S. suppliers of Navy components and in many cases, competition has altogether vanished, forcing the Navy to rely on single and sole source suppliers for critical components. Expanding the number of companies involved in Navy shipbuilding is important to maintaining a healthy industrial base.

A sole source issue currently impacts the manufacturing and refurbishment of shafts for surface ships and submarines. The limited capacity of the equipment at the sole forge doing this work for the Navy hampers the forge's ability to meet demand. Further, it is difficult to recruit and retain qualified personnel to operate the equipment because technical schools have stopped training on the equipment, given its age. If the forge is not modernized, the facility may exit the market, causing disruptions to multiple Navy programs.

Capacity Shortfall

The high operational tempo of the Navy in recent years, along with a lack of steady funding for maintenance and modernization, has resulted in a backlog of repair work across the fleet. Coupled with increases in new ship construction, many suppliers are experiencing a shortfall in their capacity to perform work and manufacture products. This increased demand is applying stress to already-aging production equipment and could necessitate additional hiring in highly specialized fields, where it is difficult to find suitable candidates. The combination of limited suppliers and an increase in workload could increase cost and potentially create schedule slips, impacting American warfighting capability.

One risk in particular relates to Navy surface ship dry-docking requirements for maintenance and modernization work. New ship technical requirements, a large volume of mid-life availabilities, and a general lack of investment by industry in new dry-dock capacity will create a significant constraint for completing ship maintenance, requiring the Navy to adopt strategies that could potentially increase cost and schedule risk.

Lack of Competition

The primary cause decreasing competition in shipbuilding is the small comparative size of the U.S. commercial shipbuilding industry compared to the foreign shipbuilding industry, coupled with the Navy's unique military requirements. Products and services that lack competition are at a higher risk of being offered by a single or sole source supplier. Examples of lack of competition can be seen in many products critical to shipbuilding such as high voltage cable, propulsor raw material, valves, and fittings.

Lack of Workforce Skills

The skills needed to fabricate components for and build Navy ships, submarines, and their components are unique and specialized. As the shipbuilding industry has long been challenged by an eroding skill base, today's workforce will be challenged to meet the increased demand in the Annual Long-Range Plan for Construction of Naval Vessels for FY 2019. Additionally, the Department of Labor predicts that between 2018 and 2026, there will be a 6%–17% decrease in U.S. jobs in occupations critical to Navy shipbuilding, such as metal layout (ship-fitting), welding, and casting. As the amount of available jobs overall in the U.S. decreases, the number of workers entering into these fields will also decrease. Left unaddressed, a lack of skilled workers will significantly impact the shipbuilding industry's ability to meet the Navy's long term demand.

Unstable Demand

Due to uncertainties about future budgets and shipbuilding plans, the supplier base is limited in their ability to plan for future work, which limits production efficiencies, inhibits investment in facility improvements and workforce development, and reduces the level of independent R&D investment. Perhaps most significant, decreases and instability in demand can result in workforce reductions and production lines being shut down. When this happens, it is difficult to bring those skills back when they are needed, as it takes a significant amount of time to train a workforce to acquire the skills unique to the shipbuilding industry, and specialized production lines are often costly to reopen. Unstable demand drives cost, schedule delays, and quality issues throughout the industrial base, especially if not proactively managed.

[††] An establishment is a single facility regardless of ownership. For example Company "X" could own and operate five foundries in different states within the U.S.; this would count as five establishments.

Soldier Systems Sector

Soldier systems include products necessary to maximize the Warfighter's survivability, lethality, sustainability, mobility, combat effectiveness, and field quality of life by considering the Warfighter as a system. This sector includes the weapons, body armor, clothing, footwear, radios, sensors, power supply, shelters, food, and other Service-member support items essential to executing the many distinct U.S. military missions – from snipers to tankers to airmen to divers.

The soldier systems sector is composed of twelve subsectors; most have significant commercial overlap. The subsectors are vast – a recent Department of Commerce survey, exclusively studying the domestic clothing, textiles, and footwear industries, reported that 499 companies operate 764 domestic textile and/or apparel manufacturing sites and 44 companies operate 65 U.S. footwear manufacturing facilities.

The commercial market provides stabilizing peacetime revenue for existing defense contractors as well as opportunities for new players to modify commercial gear and enter the defense market. While access to the commercial market improves industrial base robustness, it also means the commercial market may drive demand and that DoD is not always the primary customer. When military and commercial requirements differ sufficiently, commercial market dominance can directly impact lead time, surge capacity, and the sustainment or development of industrial capabilities. Often, DoD is left to adapt to commercial market driven changes and only when unacceptable levels of industrial base risks arise, DoD may intervene in order to sustain critical industrial capabilities.

The soldier systems sector is emerging from a long-term war sustainment effort where the focus has largely been on fulfilling immediate needs. The challenge of meeting dynamic wartime demands consumed most of the available bandwidth and left little room for forward-looking investment and strategic planning. Many programs have met or are approaching their acquisition objectives, which triggers a natural peacetime cycle of decreased defense demand

leading to consolidation, reduction in capacity, loss of capability, reduced capital investment, and a transition toward commercial markets. Peacetime industrial readiness losses are largely anticipated, and have historically been recovered or replaced by alternatives once the U.S. enters another large scale military engagement.

As the war effort winds down, DoD and industry are pursuing some modernization efforts. Future soldier systems objectives include lightening the soldiers' load, capitalizing on lessons learned after years of fighting, developing modular/flexible/agile materiel solutions, and taking advantage of advancements in sensor technology and materials engineering. A skilled workforce and modernized industry is required to achieve advanced designs and develop novel industrial capabilities.

Case Studies: Soldier Systems Sector Impacts on National Security

Industrial capability gaps in the soldier systems sector directly reduce U.S. assurance that the Warfighter is adequately prepared to successfully execute defense missions in any operating environment. The case studies illustrate where industrial base risk has accumulated in ways that may exceed industrial base elasticity and the risk of permanent capability loss is enough to potentially warrant government action.

Erosion of U.S. Textiles Industry

Between 1995 and 2009, the U.S. textile industry suffered a historic contraction and Asian markets now dominate global textiles supply. According to a recent Department of Commerce survey, the greatest competitive disadvantages in the domestic clothing and textile subsector are related to workforce and raw material cost and availability. Since 2009, the domestic textiles industry has shown signs of recovery, but recent data indicate a potential stall: total sales and exports of U.S. manufactured clothing and textile products have been stagnant from 2012-2016. As an example of recent domestic erosion, the single qualified domestic source for high-tenacity polyester fiber used in many DoD tent systems dissolved their business due to inability to compete in an increasingly competitive global market. Currently, there is no U.S. manufacturing capability for high-tenacity polyester fiber at specific deniers (e.g., that allow for military specification qualification) and significant impact to multiple tent and fabric systems is anticipated. If risk in the clothing and textiles subsector is unacceptable, the industry recovery momentum must be sustained and the U.S. must undertake decisive efforts to modernize and revitalize the domestic fiber and textiles industry, including the workforce.

Erosion of U.S. Rechargeable and Non-Rechargeable Battery Industry

Characterized by irregular demand proportional to operational tempo, the military battery industrial base is diminishing. Military-unique requirements can depart from commercial demands in size, quality, safety, power density, weight, and environmental ruggedness. Lack of stable production orders has resulted in lost capability and capacity, increased surge lead

times, workforce erosion, and inhibited investments by remaining suppliers. Surge-capacity-limiting constraints occur at several points along the value chain, from raw material to final battery assembly. Additionally, foreign dependencies on essential raw minerals (e.g., lithium) may potentially impact the rechargeable and non-rechargeable battery supply chain.

Most battery configurations are produced by single sources of supply. Production of BA-5590 (i.e., preeminent non-rechargeable military battery) is currently single-sourced to a foreign-owned supplier in France, with one domestic production facility. Decline in demand for military-unique non-rechargeable batteries has resulted in capability and capacity loss and the supplier can no longer support any significant surge in demands. Even when there were two manufacturers, their combined output struggled to meet surge demands for Operation Iraqi Freedom and Operation Enduring Freedom.

Asian markets dominate the rechargeable battery industry. Domestic rechargeable battery producers cannot compete in production volume and labor availability and cost. Most domestic lithium ion cell packagers rely on foreign commercial lithium ion cell suppliers from countries such as South Korea, China, and Taiwan. Cell availability for military battery packaging is a risk across the board for rechargeable batteries as commercial cell manufacturers, often foreign-owned, are unwilling to divert production from their commercial customers to U.S. military battery manufacturers.

Foreign Reliance for Essential Night Vision Components

U.S. military "night vision" systems are enabled by an image intensifier tube, a vacuum sealed tube that amplifies a low light-level scene to observable levels. Although probability of interruption has proven low (surge demand during Operation Iraqi Freedom and Operation Enduring Freedom was met) and there is a stockpiling risk management strategy in place, the U.S. is reliant on foreign capabilities to supply image intensifier tube core glass from Germany and gallium arsenide photocathodes from Japan and Germany. Core glass is DoD-unique and demand is very low compared to commercial glass production; the foreign sole source manufactures the core glass in batches based on demand, every few years, to replenish a U.S. buffer stock. Gallium arsenide allows for a more efficient conversion of light to electrical energy at extremely low light-level so by adding gallium arsenide to the photocathode, a brighter and sharper image is achieved. Gallium arsenide risk is considered reduced as the number of global suppliers has increased over time.

Space Sector

The space sector (also known as National Security Space) includes satellites, launch services, ground systems, satellite components and subsystems, networks, engineering services, payloads, propulsion, and electronics.

National Security Space increasingly leverages the commercial space industry, both domestic and foreign. While commercial space has similar needs to DoD, it does not require the same level of robustness, reliability, and security in its products. Many National Security Space domestic products are commercially non-competitive, due to the leading-edge performance, high-level capabilities, and unique DoD requirements. Commercial space relies on satellite replacement rather than long-term mission capability and while National Security Space systems continue to leverage commercial space products, there are certain performance requirements and capabilities that are more demanding or unique and are not supported by the growing commercial space ecosystem. DoD and U.S. Government-wide studies and analyses have identified at-risk capabilities, fragile suppliers, and stress in the lower tiers of the space industrial base. Primary areas of concern, as identified in the Defense Production Act Title III Presidential Determination (15 June 2017) include: aerospace structures and fibers, radiation-hardened microelectronics, radiation test and qualification facilities, and satellite components and assemblies.

The DoD space industrial base remains a niche market with very specialized and capital-intensive capabilities that are not efficiently managed through individual program investments. Many systems currently in planning and development rely on dated technology, skills, and fragile sources. Individual programs are reluctant to invest in and qualify new technology and sources, creating a need to sustain fragile domestic sources and to qualify new technologies and sources for next-generation systems, which are essential to address ever-increasing threats in the space domain.

The Space Industrial Base Working Group[##] maintains critical technology lists from member agencies which are integrated and prioritized to establish space industrial base risk mitigation projects. Prioritized, but unfunded, mitigations for over a dozen of the top issues have been developed, along with tracking of over 100 additional lower risk issues. DoD must remain vigilant of sources of vulnerability and maintain critical capabilities that are specialized for military applications.

Space systems provide an emergent capability and strategic advantage to U.S. forces yet, due to DoD business practices, market trends, supply chain globalization, and manufacturing costs, future access to space qualified domestic industrial sources, including microelectronics, is uncertain. Increasing cyber-threats, non-trusted supply-chains, foreign acquisitions, reliance on vulnerable foreign sources, industrial policies of competitor nations (in the form of subsidies, domestic preference, etc.), and erratic demand is threatening the loss of essential space capabilities and critical skills.

Case Studies: Space Satellite Sector Impacts on National Security

Gaps in the space sector result in a limited or degraded domestic supply of qualified critical materials and components to support National Security Space missions. The case studies below illustrate how high-performance and high-reliability requirements, long development cycles with low and inconsistent demand, and erratic funding further reduce the strategic advantage of the U.S. in the space sector.

Precision Gyroscopes

Precision gyroscopes are a critical component of the attitude determination and stabilization and inertial navigation system on spacecraft, launch vehicles, and missiles. Three or more individual gyroscope inertial sensors are typically packaged in an internally redundant inertial measurement unit. Three different types of gyroscopes (ring laser, hemispherical resonating, and fiber optic) are generally employed in space systems, each with varying industrial base issues. Hemispherical resonating gyroscopes are an older technology mainly used on non-agile satellites and only one domestic provider remains with limited production capacity (one or two units per month). As a result, this low volume item is frequently impacted by obsolescence issues and long lead times which can impact unit delivery if failures are found in testing.

The fiber optic gyroscope is the main technology employed in high performance agile spacecraft and missile applications. While there are currently three domestic suppliers, fiber optic gyroscopes rely on key components – integrated optics chips and laser diodes –

[##] The Space Industrial Base Working Group includes DoD's Office of Industrial Policy, Air Force Space and Missile Systems Center, Missile Defense Agency, and National Reconnaissance Office; the National Aeronautics and Space Administration is also an active participant.

experiencing supply issues which threaten the viability of domestic product lines. The sub-components used in integrated optics chips are increasingly manufactured overseas and laser diode suppliers are consolidating and also moving manufacturing offshore.

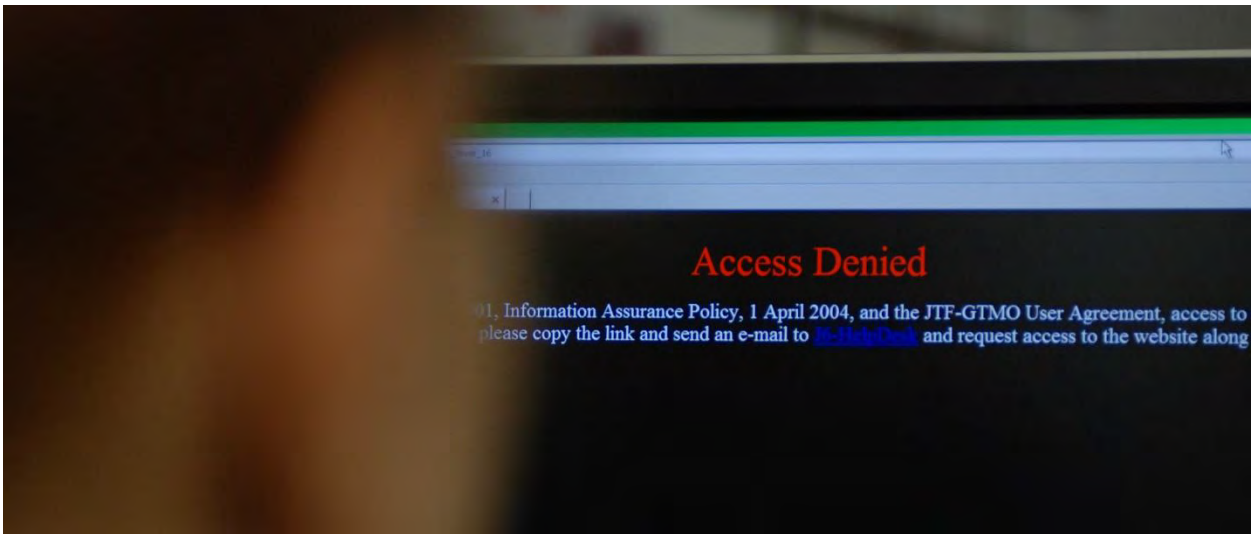
Space Qualified Infrared Focal Plan Arrays

The manufacture of space infrared detectors is dependent on a single foreign source for high quality substrates, and driven by low volume and long periods between orders, resulting in quality and workforce issues. Space infrared detectors rely on both mercury cadmium telluride and cadmium zinc telluride substrates. Despite a Defense Production Act Title III investment over the past few years used to establish a domestic provider and improve manufacturing capability for cadmium zinc telluride substrates, any disruption of more than a few months could essentially shut down production of large, strategic quality, mercury cadmium telluride infrared focal plane arrays and impact quality and long lead items for space satellites. A complimentary Industrial Base Analysis and Sustainment program is aiming to sustain the two U.S. foundries through process improvements, as well as demonstrate that domestic cadmium zinc telluride substrate-based detectors are equivalent in performance to focal plane arrays utilizing off-shore substrates.

The potential loss of domestic read-out integrated circuits sources for space applications due to low volume production will force systems to foreign vendors or to limited performance technologies that will severely impact on-orbit lifetime. This could also result in loss of domestic read-out integrated circuits design expertise, critical to integration into the sensor chip assemblies which make up focal plane arrays utilized for missile early warning, missile defense, space surveillance, and awareness in space systems. Radiation hardened, digital, capacitance trans-impedance amplifier based read-out integrated circuits have no commercial applications, resulting in extremely low volume production. The space market for read-out integrated circuits is extremely small, representing less than 1% of business for existing suppliers.

Cross-Cutting Sectors

Cybersecurity for Manufacturing Sector



Cybersecurity for manufacturing is a complex and challenging issue with immediate impacts to all facets and sectors of the industrial base. It includes information technology and operational technology within and across the supply chain.

The defense manufacturing supply chain flows goods and critical information among multiple organizations – of varying size and sophistication – to transform raw materials into components, subassemblies, and ultimately finished products and systems to meet DoD performance specifications and requirements. These supply chain operations rely on an infinite number of touch points where information flows through a network – both within and across the many manufacturers' systems that constitute the supply chain. In today's digital world, every one of these supply chain touch points represents a potential vulnerability to the security of our nation's defense production.

According to private sector reports, in 2014, manufacturers received the greatest volume of targeted cyber-attacks of all industries globally,[132] primarily for espionage purposes.[133] In 2015, the Department of Homeland Security reported the manufacturing sector received the highest number of attacks on industrial control systems of any critical infrastructure sector, at nearly twice the 2014 level. Sophisticated cyber-espionage campaigns seeking to alter the automation of physical processes on manufacturing lines continue to pose a significant threat.

Of the approximately 347,000 manufacturers in the United States, 99% are small and medium-sized manufacturers, yet more than 50% lack basic cyber controls. An assessment by Bureau of Industry and Security illustrated the cybersecurity vulnerability of small manufacturers. The survey of over 9,000 "classified contract facilities" documented that 6,650 small facilities lagged

medium and large firms across a broad range of 20 cybersecurity measures. It also found that fewer than half of the small firms had cybersecurity measures in place.[134]

Certain defense manufacturing supply chain operations occur in classified and very tightly controlled environments, but most information generated, stored, and exchanged is not classified. The protection of such unclassified, covered defense information (including controlled unclassified information) presents an enormous and complex challenge and vulnerability. Most of the manufacturing data of interest to adversaries is essentially controlled unclassified information. This includes design information; performance specifications; shop floor execution data; factory support information (e.g., financials, system status, and personnel); and supply chain operational information (e.g., invoicing, pricing, and contract volume).

Both the public and private sectors recognize the importance of safeguarding informational and operational assets from cyber risks; however, cybersecurity has not become an ingrained norm in manufacturing, especially in small and medium-sized manufacturers.[135] Many small and medium-sized manufacturers are unaware of federal requirements and may lack the financial and technical capabilities required to manage cybersecurity risks.[136] Defense Federal Acquisition Regulations Supplement clause 252.204-7012 requires defense contractors and subcontractors to have implemented the information security protections described in the National Institute of Standards Special Publication 800-171 Rev 1, "Protecting Unclassified Information in Nonfederal Information Systems and Organizations" by December 31, 2017, but initial compliance by sub-tier suppliers has been low.

Case Studies: Cybersecurity for Manufacturing Impacts on National Security

Gaps in the cybersecurity sector lead to pervasive and persistent vulnerabilities to the industrial base, contributing to the erosion of manufacturing and decreasing economic competitiveness and national security. The case studies below illustrate how unauthorized access to any facet of manufacturing information could create rippling effects and cause innumerable negative economic and national security situations.

Inadequate Approaches to Cybersecurity Risk and Inadequate Cybersecurity Defense

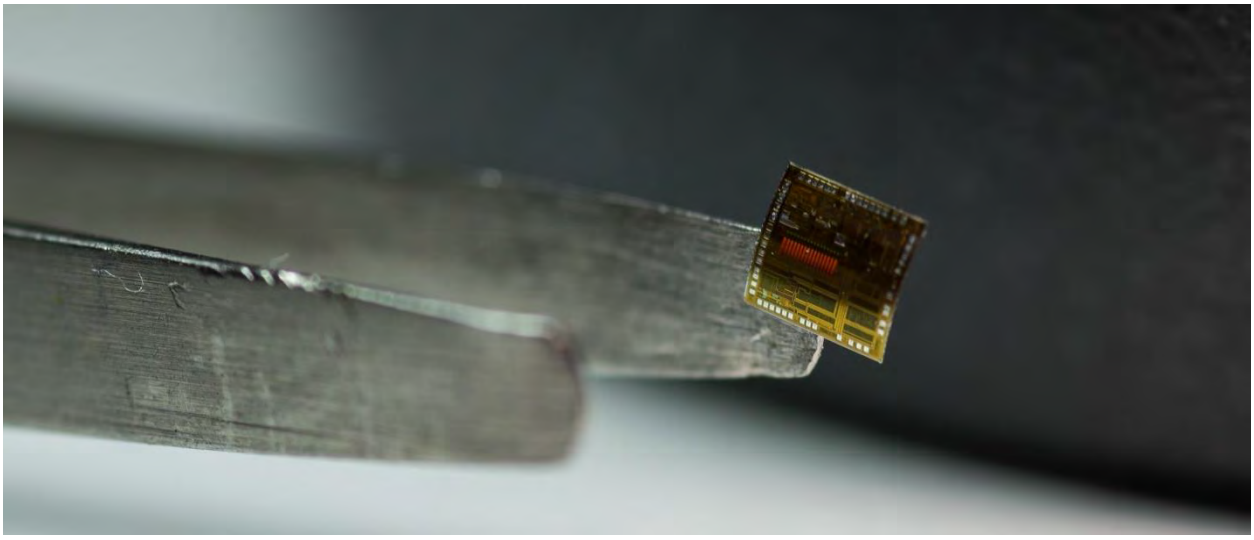
Cybersecurity risks impact all facets of manufacturing supply chain operations, from product and process data flowing within and across factories, to supply chain operations and logistics, to the reliability of tools and equipment used within manufacturing enterprises. Multiple approaches exist to manage cybersecurity risks within the industrial base, but not all approaches are appropriate or even adequate to meet the national security need to protect covered defense information and controlled unclassified information. Three key issues – lack of uniform security implementation; inconsistent implementation of adequate security by defense suppliers; and reliance on self-attestation – expose manufacturing to cybersecurity risks. Interactions with over 1,000 small manufacturers by the Department of Commerce

Manufacturing Extension Partnership National Network in 2017 revealed a significant lack of awareness of the Defense Federal Acquisition Regulations Supplement cybersecurity requirement, and a deficiency of financial and technical resources to manage cyber security risks. In addition, many sub-tier suppliers are unaware they are in the DoD supply chain and others who are aware are subject to conflicting interpretations of the requirement by agencies and upper tier customers.

Inadequate Cybersecurity Defense for the Defense Manufacturing Supply Chain

Manufacturing is the most heavily attacked sector in the economy after finance, so the industrial base is subject to continuous, coordinated cyber-attack campaigns by nation states. As new types of cyber threats and vulnerabilities targeting manufacturing supply chain-specific information and operational systems emerge, the U.S. cannot rely on small and medium-sized manufactures to protect against attacks from nation states. Unfortunately, most cybersecurity research and development is focused on information systems, without specific emphasis on the unique needs and operational aspects of the manufacturing sector. If unaddressed, the industrial base faces a higher likelihood of serious and exploitable vulnerabilities, as well as a substantial reduction in the number of suppliers compliant with requirements and thereby eligible to provide products and services to DoD. Further, commercial firms considering entrance into the defense market will be deterred. This combination of risks will impact both the resiliency of existing suppliers and the integrity of the supply chain.

Electronics Sector



Greater than $1.5T, the electronics sector manufactures products for a wide variety of end user markets, including consumer electronics, computers, automotive, industrial equipment, medical equipment, telecommunications, aerospace, and defense. Electronic systems and components

are ubiquitous throughout all DoD weapons systems, but global military production represents only 6% of a market dominated by commercial devices.[137] While significant compared to overall worldwide military spending, total U.S. military spending on electronic systems in 2017 is insignificant compared to the overall aerospace and defense marketplace, as well as the commercial market, giving DoD limited leverage over the direction of the industry.

In electronics, staying competitive requires a significant investment in R&D, new production facilities, and new equipment. The U.S. semiconductor industry spends 18.5% of sales on R&D, more than any other U.S. industry, with the exception of pharmaceuticals and biotechnology,[138] and the sector is driving industry consolidations and offshoring. At the prime contractor level, approximately 50% of contract expenditures related to computer and electronic product manufacturing went to the top five suppliers, including three major defense contractors.[139] Below the prime contractor level, electronics is a global industry, with a supply chain spanning multiple countries and regions, creating a high degree of interdependence among suppliers and profound implications for DoD.

Printed circuit boards provide the substrate and interconnects for the various integrated circuits and components that make up an electronic system. Like the overall electronics market, the global printed circuit board market has experienced explosive growth – from $30 billion in 2000 to $60 billion in 2015.[140] However, this growth has mainly been driven by China, which now captures 50% of the global market share, while the U.S. share has reduced from 25% in 1998 to less than 5% in 2015.[141]

Microelectronic integrated circuits are the most technologically advanced level of the electronics supply chain. Since 1996, the global market for semiconductors has increased from $132 billion to $339 billion in 2016, with the Asia Pacific market outside of Japan accounting for the vast majority of this growth. The market quintupled in size from approximately $39 billion in 1996 to $208 billion in 2016, including a $107.6 billion market in China alone (approximately 9 % increase over 2014). Asia, where much of electronics production takes place, is by far the largest customer base for U.S. semiconductor companies, accounting for approximately 65% of all U.S. sales, with sales to China accounting for slightly more than 50%. U.S. companies continued to hold a majority of the Chinese semiconductor market in 2016 with 51% share, marking a drop from 56% in 2015.[142] Maintaining access to the Chinese market is a critical concern for U.S. semiconductor companies.

The U.S. continues to hold a strong position in semiconductor manufacturing and has become a leader in microelectronics design by using the fabless model, focusing on integrated circuit design, and outsourcing fabrication to dedicated foundries.[143] Increasingly, however, fabless companies are investing in design capabilities and services offshore. To address these threats, DoD is investing in trusted foundry capabilities to serve critical defense needs, and is working with interagency partners to develop the Microelectronics Innovation for National Security and Economic Competitiveness strategy to address current and future microelectronics needs, threats to assured access to a robust industrial base, and continued U.S. leadership.

Case Studies: Electronics Sector Impacts on National Security

Gaps in the electronics sector reduce the ability deliver technological advantage in capability, performance, and reliability against adversaries. The case studies below illustrate the increasing divergence of commercial business models and defense requirements in electronics.

Strategic Radiation Hardened Microelectronics

Strategic radiation hardened microelectronics are a critical component of the nuclear deterrent; they must be able to withstand short bursts of intense radiation and high temperatures in order to satisfy mission requirements not commonly required commercially. Strategic radiation hardened and DoD defense-unique requirements have no commercial applications and are commercially unviable, creating continual risk for this critical capability due to changing business conditions or technological obsolescence.

DoD continues to ensure a domestic source of strategic radiation hardened microelectronics through investing in R&D on radiation hardening design techniques and radiation effects on state-of-the-art and state-of-the-practice semiconductor technologies. Additionally, DoD is broadening the strategic microelectronics supplier base by developing alternate trust models, processes, and techniques, and continuing to work closely with partners in the strategic community.

Printed Circuit Board Manufacturing

U.S. printed circuit board manufacturing struggles to remain current and relevant in the global marketplace. Today, 90% of worldwide printed circuit board production is in Asia, over half of which occurs in China. The United States accounts for only 5% of global production, representing a 70% decrease from $10 billion in 2000 to $3 billion in 2015. As a result of this decline, the U.S. industrial base is aging, shrinking, and failing to maintain the state of the art for rigid and rigid-flex printed circuit board production capability. Capability indicators (such as laser drills and direct imaging tools) are not prevalent across many domestic manufacturer facilities, with some advanced high density interconnect products simply not producible in the U.S. While commercial technology advances are frequently developed in the U.S., they are resolved to practice offshore.

With the migration of advanced board manufacturing offshore, DoD risks losing visibility into the manufacturing provenance of its products. In addition to the potential dissemination of design information, many of the offshore facilities do not meet or comply with DoD quality requirements. The DoD Executive Agent for Printed Circuit Board Technology has provided technical assistance activities with domestic manufacturers and observed awareness gaps among manufacturers related to International Traffic in Arms and other Export Control regulations, leading to the potential for further unintended dissemination of sensitive information. As the equipment and materials supply chain has followed the migration of the manufacturer base, supply chain and supplier management is becoming a risk driver for access and availability.

Machine Tools and Industrial Controls Sector

Machine tools are power-driven machines used to shape or form parts made of metal, plastic, or composites to support both production and prototyping operations. They are critical to creating modern products for defense and industry, and impact transportation, aerospace, electronics, energy generation and distribution, and other critical infrastructure sectors.

Machine tools provide the factory floor foundation for leveraging advances in robotics, high precision automation, specialty materials, precision components, and additive, subtractive, and hybrid machining. Controlled via manual inputs, analog systems, or digital controls, machine tools require inputs from a variety of sources: ferrous and non-ferrous metals and alloys, including forgings and castings of various sizes; rubber, plastics, and composites; high-precision screws, nuts, and bolts; bearings; and motors, drives, and computer numeric control capabilities. Modern machine tools leverage sophisticated industrial control systems, process parameter monitoring systems, and networked sensors. Many also incorporate advanced materials and precision components, as well as advanced lubricants, bearings, sensors, and coatings.

Case Studies: Machine Tools and Industrial Controls Sector Impacts on National Security

Loss of key capabilities within the domestic machine tools industry erodes U.S. ability to maintain manufacturing dominance, which underpins technical and economic superiority, fundamental elements of national security. The case studies below illustrate how decreasing U.S. manufacturing market share, reductions in the needed workforce, and reduced competitiveness in the global market impact the machine tool sector in the U.S.

Inadequate U.S. Skilled Labor Supply

The U.S. machine tools sector lacks assured access to a sufficiently large pool of skilled labor. Many skilled workers are exiting the workforce due to age, and there are too few technical educational programs to train those who could take their place. Without concerted action that provides both a ready workforce and a continuously-charged pipeline of new employees, the U.S. will not be able to maintain the large, vibrant, and diverse machine tools sector needed to produce the required number and types of products when needed.

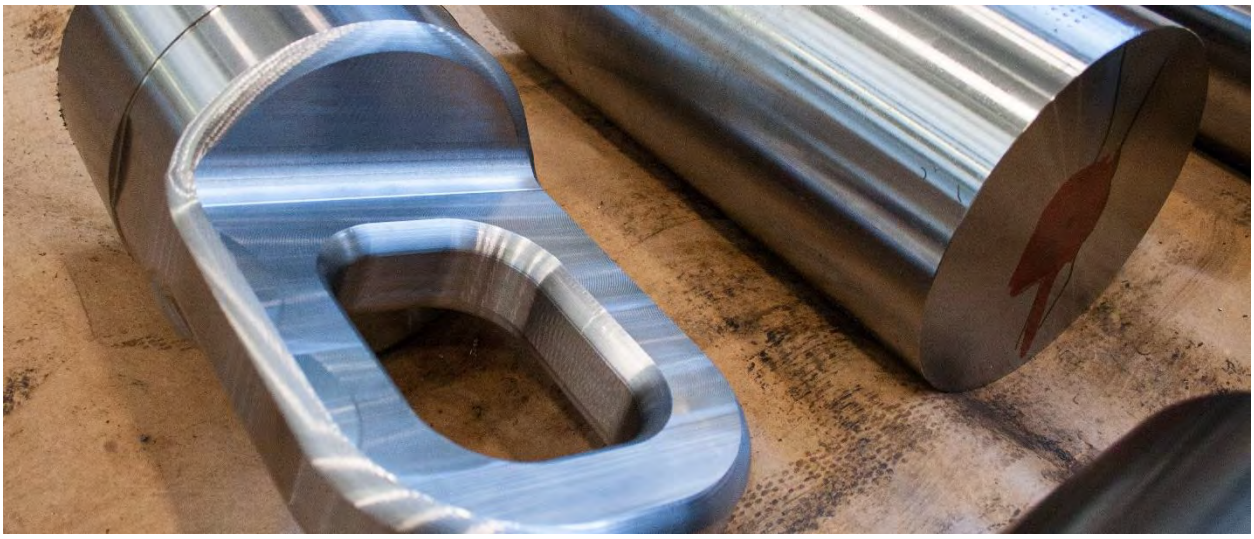
Market Forces Decreasing Domestic Capabilities

The U.S. machine tools sector has been shrinking since at least the 1980s due to a number of primary and contributing factors,[144] with the U.S. standing dropping significantly since 2000. In this mature, highly commercialized market, competition on price and quality[145] is fierce, and many firms have found themselves in a poor position to leverage emerging computer numerical control capabilities. Until the mid-2000s, China accounted for no more than 15% of global machine tool consumption. By 2011, China's machine tool consumption accounted for 40% of the global total.[146] As its need for machine tools increased, China leveraged its low cost of capital and labor to build domestic machine tool factories and required foreign companies to execute joint ventures to access the Chinese market. The combined effects of the 2008 recession and a general trend of industry consolidation further reduced the number of machine tool manufacturers. In 2015, China's global machine tool production skyrocketed to $24.7B,[147] accounting for 28% of global production,[148] while the U.S. accounted for only $4.6B, after China, Japan, Germany, Italy, and South Korea. According to the U.S. Census Bureau data, in 2015 there were 1,028 machine tool firms employing 27,919 people.

Cybersecurity Risks

While the cybersecurity industry has placed heavy emphasis on protecting traditional information technology systems used in manufacturing enterprises, far less attention has been paid to the operational technology systems that actually manufacture products. This includes machine tools and industrial control systems, which are increasingly being linked through internet protocol addresses for valid business reasons. The unintended result is a dramatic, potentially decisive, increase in the manufacturing cyberattack surface. A significant constraint on DoD's ability to respond to all cybersecurity risks is a lack of visibility into the lower tiers of the supply chain.[149]

Materials Sector



Materials are vital to national defense and economic security. While defense demand may often represent a small fraction of overall domestic and foreign supply, there are important subsectors that are heavily defense dependent. It is imperative that producers and supply chains of materials deemed essential to U.S. defense and civilian demand are robust, resilient, competitive, and responsive to support current and long-term economic security, current military operations, future wartime mobilization, and unanticipated surge demand.

The sector includes both raw and "downstream" materials produced by a global supply chain of value-added processing and manufacturing companies. These and other materials are combined into intermediate, semi-processed, and finished materials and eventually produced into end-items (e.g., parts, components, or structures) and incorporated into subsystems and integrated systems.

The range of materials is broad and includes metals and nonmetallic minerals produced from mining of primary materials or as a byproduct (e.g., rhenium from copper mining), or reclamation (e.g., recycling rare metals from electronics).[150] Of equal or greater importance to raw material supply is industrial-scale capabilities and sustainable capacity to extract elements from mined materials and to produce value-added products. Examples include separating elements, processing compounds, smelting metal, alloying, and further downstream production (e.g., castings, forgings, and rolled products), particularly for the processing of rare earth elements. Important defense applications include high-performance aluminum and steel for ground vehicles and Navy ships; titanium and beryllium for military aircraft; tungsten for radars and communication systems; rare earths for guided munitions and computers; and ceramics for body armor and microelectronics. Another subsector is highly engineered synthetic materials and their composites, such as carbon fibers for missiles, aircraft, and space system structures; fibers and textiles for protective apparel and vehicle survivability; and synthetic materials

including energetics for explosives and propellants. Newer materials of increasing importance include carbon nanotubes and additive manufacturing materials.[151]

Within the materials sector, risk includes shortfalls that impact the production of defense items to support current military operations; high U.S. import reliance on foreign countries who may become adversaries and cutoff supply during conflicts (e.g., trade embargo or war damage);[152] reliance on single foreign sources of proprietary materials that would be difficult to replace; injurious foreign trade impacts (e.g., dumping and illegal subsidies) on key DoD suppliers; DoD reliance on commercial materials that become obsolete; and dependence on domestic single-point-of-failure producers.

Case Studies: Materials Sector Impacts on National Security

Highlighted below are three case studies which highlight important materials-related risk impacts. Please see the limited distribution annex for further details about specific materials risks, estimated shortfalls, and mitigation recommendations.

Over Reliance on Sole Foreign Sources for Unique and Proprietary Advanced Materials

Single foreign sources of unique and proprietary carbon fibers from Japan and Europe represent considerable DoD supply chain vulnerabilities. A sudden and catastrophic loss of supply would disrupt DoD missile, satellite, space launch, and other defense manufacturing programs. In many cases, there are no substitutes readily available. Replacing a carbon fiber factory is very expensive and time consuming. Of similar concern is the uncertainty of qualifying replacement suppliers and significant resource requirements.

Injurious Foreign Trade Impacts on Critical U.S. Material Manufacturers

Unlawful and/or otherwise unfair foreign trade practices, mostly by China, are injuring critical U.S. materials-related manufacturers. Predatory practices – including state-sponsored dumping, market distorting government subsidies, and intellectual property theft – are destroying commercial product lines and markets of domestic DoD suppliers. In some cases, U.S. suppliers have lost much, and at times all, of their commercial markets supporting dual-use production lines that manufacture key materials and components for U.S. weapon systems. The loss of commercial business can lead to the loss of domestic production capabilities essential to U.S. defense and essential civilian needs. In multiple cases, the sole remaining domestic producer of DoD-critical materials are on the verge of shutting down their U.S. factory and importing lower cost materials from the same foreign producer county who is forcing them out of domestic production. Without relief from unlawful and otherwise unfair foreign trade, the U.S. will face a growing risk of increasing DoD reliance on foreign sources of critical materials. Examples include domestic producers of specialized metals, alloys and other materials that are widely used across multiple DoD programs and all major

defense sectors (e.g., land, sea, air, and space systems).[153] Of special concern are U.S. imports that undermine domestic producers of materials protected under the Buy American Act, Berry Amendment and Specialty Metals Clause.[154] [155]

Overreliance on China for Strategic and Critical Materials

A key finding of this report is that China represents a significant and growing risk to the supply of materials deemed strategic and critical to U.S. national security. In addition to China dominating many material sectors at the upstream source of supply (e.g., mining), it is increasingly dominating downstream value-added materials processing and associated manufacturing supply chains, both in China and in other countries.[156] Areas of concern to America's manufacturing and defense industrial base include a growing number of both widely used and specialized metals, alloys and other materials, including rare earths and permanent magnets.

Organic Industrial Base Sector

The organic industrial base, a subset of the larger defense industrial base, is comprised of resource providers, acquisition and sustainment planners, and manufacturing and maintenance performers. While commercial industry is the dominant component of the industrial base, government-owned, government operated maintenance depots, shipyards, and manufacturing arsenals are critical to U.S. defense. They provide the assurance of a ready and controlled source of technical capabilities necessary to maintain weapon systems free from many of the economic vulnerabilities and influences that exist in the private sector. This means that every military ship, plane, vehicle, and weapon is accompanied by a government-owned ecosystem that includes expertise to perform deep repair, the means to provide repair parts to the shop floor, and the ability to deliver repaired systems to the time and place of the fight. The organic base complies with legislation to provide core logistics capabilities, including personnel,

equipment, and facilities that are government-owned, government operated. The law prescribes these capabilities as inherently governmental and has allowed for the development of highly capable depot artisans and military logisticians.

The organic industrial base provides maintenance and manufacturing services to sustain approximately 440,000 vehicles, 780 strategic missiles, 278 combatant ships[157], and almost 14,000 aircraft.[158] Of $587.9 billion total DoD expenditures in FY 2015,[159] $73.4 billion was for maintenance. Aircraft represented the greatest expenditure at $25 billion, followed by ships at $16.8 billion, and vehicles at $7.7 billion.[160] DoD currently operates 17 major organic (government-owned, government operated) depot maintenance facilities and three manufacturing arsenals.

DoD maintenance is performed by a military and civilian workforce spread throughout the world. DoD materiel maintenance is performed at different organizational levels, ranging in complexity from daily system inspection to rapid removal and replacement of components, to the complete overhaul or rebuild of weapon systems. Depot-level maintenance entails the major overhaul or complete rebuild of weapons systems and requires skills or equipment not commonly available at lower levels of maintenance. Organic depot-level maintenance also includes software maintenance and sustainment, which incorporates correcting defects, improving performance, upgrading, and modifying software to adapt the fielded software baseline to a changing or changed environment.

Twenty years of intermittent conflict and war have driven a very high operating tempo and unprecedented system usage that has changed previously accepted formulas used to compute maintenance requirements. The levels of funding and the manner in which funding has been made available and allocated to these sustainment operations have degraded our ability to achieve expected performance results. The organic industrial base has suffered from overuse and underfunding in its infrastructure and the evidence is clearly reflected in materiel readiness levels and facility condition indices. Workforce issues have been exacerbated by sequestration, gaps in critical skills, and gaps in hiring. Diminishing manufacturing sources and material shortage, counterfeit, foreign manufacturing, and single source of supply issues represent further risks to the ability of the organic base to influence materiel readiness through the degradation of supply chain integrity and availability of critical materials and human capital necessary to maintain weapon systems.

Case Studies: Organic Base Sector Impacts on National Security

Gaps in the organic base sector directly impact the ability to repair equipment and materiel as quickly as possible and ensure its availability for training and future deployments. The case studies below illustrate the critical need to ensure continuity of operational readiness during times when the private sector may not be able to meet surge requirements.

Deficiencies in Maintenance Facility Material Condition

Currently, a lack of available and effective capacity within government owned industrial activities, coupled with a high near-term workload, is causing a capacity to workload mismatch. This mismatch continues to drive maintenance delays and an increased loss in operational days.

DoD has accelerated investments in its Capital Improvement Programs and the replacement and modernization of minor property to better align with industry recapitalization standards. These efforts and review of work backlogs, stoppages, and cost and schedule metrics are targeted to reduce lost operational days, to facilitate on-time availability completions, to provide adherence to training schedules, and to ready forces to meet deployment and surge requirements.

Maintenance

DoD is operating many of its weapon systems well beyond their original designed service lives. Coupled with increased operating tempo and exposure to harsh environmental conditions, these platforms require engineering and overhaul processes far more extensive than those performed under historical organic industrial base infrastructure alignments. The infrastructure has not been refreshed to adequate levels of repair and technology modernization.

Organic base depots are Working Capital Funded activities and required to reinvest and recapitalize equipment and facilities through their rate structure. Sensitivity to rate increases limits each depot's ability to modernize and restore infrastructure to the extent required. While DoD's budget replaces and refurbishes plant equipment, and statute and policy direct follow-through on recapitalization, infrastructure investments have not been adequate. Without significant future investment, the organic base will remain challenged by outdated equipment, tooling, and machinery. The erosion of organic infrastructure continues to impact turnaround time and repair costs of newly fielded weapon systems, reducing inventory, decreasing operational readiness, and impacting future deployment schedules.

Workforce Recruitment, Retention, and Onboarding

The DoD Maintenance Enterprise faces workforce skill gaps across the board. The emergence of new weapon technologies coupled with retirements has caused a significant mismatch between skill requirements and workforce capabilities. Recruitment and retention of critical skill sets are concerns, partially because of sharp competition for labor with the private sector and due to a lack of defense specific skills. Training the new workforce is essential, and improving the organic industrial base's opportunity to recruit already trained artisans would have significant and immediate impacts on productivity and readiness. Exacerbating the issue is the lack of policy to authorize security clearance "transfer in status" when technicians who have clearances are hired; the statutory requirement outlined by 5 U.S. Code 3326

prohibiting the hire of military technicians for 180 days after separating from the military; and government shutdowns and furloughs which diminish the ability to recruit, hire, and retain talented STEM personnel.

Software Engineering Sector

The software engineering discipline has evolved rapidly over the past several decades, creating a crisis within the industrial base. Software engineering is the application of a systematic, disciplined, quantifiable approach to the development, operation, and maintenance of software. Software engineering capability includes the processes, resources, infrastructure, and workforce competencies to enable systems to meet operational mission requirements and evolving threats.

Software is virtually in every piece of electronics from firmware, operating systems, and applications. This includes DoD weapon systems, mission support systems, maintenance systems, business systems, etc. Today's modern weapon systems rely heavily on software to provide functionality. The F-35 is estimated to rely on 90% of its avionics specification requirements on software; this has grown significantly over the last four decades when the F-15A had just 35% software reliance in 1975. Unlike physical hardware, software can be delivered and modified remotely, greatly facilitating rapid adaptation to changes in threats, technology, mission priorities, and other aspects of the operating environment.

Unfortunately, software for many weapon systems is being sustained with processes developed decades ago for hardware-centric systems. In addition, much of DoD policy remains hardware-centric, despite software providing an increasingly larger percentage of system functionality. In today's fast pace changing environments with mounting cyber threats, software engineering for our software intensive systems should look to utilize agile software development processes accompanied with appropriate contracting practices capable of rapidly delivering incremental and iterative changes to the end-user.

As a result of the paradigm shift from hardware to software intensive systems, a significant need for a more software savvy acquisition workforce is essential. Policy, roles, and responsibilities for software engineering at the DoD level are not clearly established to effectively represent software equities at the acquisition policy and program levels. A lack of unified policy has resulted in various interpretations and implementations across the Services. Currently, there exists limited focus and priority on explicitly addressing software engineering sustainability of software intensive systems during the requirements process, design, and development of systems. The inventory of software that DoD currently possesses is immense and continually growing, but there is limited visibility and understanding at the enterprise level of the total size, complexity, and characteristics of the inventory, which may be exceed one billion line of custom developed software code. A unified source of clear software engineering policy would aid in a unilateral implementation of appropriate practices across the industrial base.

Exacerbating the need to strengthen organic software expertise is the issue of a national STEM shortage. Today's education pipeline is not providing the necessary software engineering resources to fully meet the demand in the commercial and defense sectors, and resources required to meet future demands continue to grow. Until the STEM crisis is rectified, recruiting, hiring, and retaining qualified personnel will continue to be challenging.

Case Studies: Software Engineering Impacts on National Security

The software engineering skills gap affects a wide range of occupations and could have potentially significant impacts on production of critical defense-related materials, vehicles, and machinery, as well as other goods and services necessary to supply our nation's armed forces. The below case studies provide specific examples.

F-35 Schedule Delays and Cost Overruns

F-35 provides an example where complexities of highly integrated hardware and software systems have led to high risks of program delays related to the release of software, further delaying the capabilities required in the field. Hardware and software delays associated with the Block 3F release, required to declare Air Force initial operating capability, resulted in a five-month delay and projected $532M cost overrun.

B-52 Mission Planning Agile Software Development

Organic software professionals in the Air Force implemented agile software development processes for B-52 Mission Planning as a pilot project in 2010. The agile processes streamlined rapid, iterative performance from development to fielding, resulting in the delivery of the project on schedule, at a cost of $28M, and included additional major capabilities. In addition, major defects discovered during the first operational test were reduced by 93% compared to similar programs. Initially, a contract was awarded to industry for this effort at $54M in 2007, but was cancelled three months later due to budget shortfalls.

Personnel Recovery Command and Control Agile Software Development

In 2014, organic sustainment engineers implemented agile software development processes for personnel recovery command and control systems. Implementation overcame poorly defined requirements while improving response time to changing needs by field units. In addition, defects found during acceptance testing were reduced by 88%.

Workforce Sector

Workforce includes the occupations for the full lifecycle development and support of defense products and inputs, including R&D, design, manufacturing, production, and maintenance.

Around 1.6 million workers have jobs that, at least in part, support national defense,[161] accounting for approximately 1.3% of private sector employment. Within the industrial base, the largest occupational groups are production workers (e.g., manufacturers such as welders and machinists) and STEM workers. The industrial base also includes workers in transportation, business and financial services, management, and office and administrative support.

Manufacturing represents a critical part of the industrial base workforce. The advanced weaponry and supporting equipment necessary to dominate in modern warfare require highly sophisticated manufacturing, yet the domestic workforce has suffered for decades. The U.S saw a sharp decline in manufacturing beginning in the 1970's, with only a moderate uptick in more recent years. The manufacturing sector lost 6 million jobs from 1998 to 2010 and while the sector has seen some gains – in January 2018, there were 12.6 million manufacturing jobs, up approximately 1 million from early 2010 – it still lost 5 million jobs since 1998.[162] The skill atrophy accompanying such loss can have profound short and long term effects on industrial capabilities.

A National Association of Manufacturers survey of 662 manufacturing companies, conducted in December 2017, found the inability to attract and retain a quality workforce is the top business challenge, cited by 72.9% of respondents. To address this workforce challenge, 66% of respondents said they are increasing the workload of their existing employees. 34.4% stated their company had been unable to take on new business and had lost revenue opportunities because of the inability to attract and retain workers.[163] Given the number of manufacturers who exist in the industrial base supply chain, these numbers are significant.

However, the manufacturing and defense industrial base does provide strong employment opportunities for growth. In January 2018, the National Association for Manufacturers reported 427,000 manufacturing job openings, with 360,000 workers hired – continuing a strong trend in hiring since August 2017.[164] Although the number of workers engaged in many traditional production occupations, such as assemblers, machine setters, and mold makers, is projected to continue to decline over the coming decade, several other occupations that enable and support the modern, automated manufacturing facility are expected to surge.

While the total number of bachelor's degrees in the U.S. has increased steadily in the last two decades, the number of STEM degrees conferred in the U.S. still pales compared to China.[165] In addition, the U.S. has seen an increase in students on temporary visas, many of whom would be unable to gain the security clearances needed to work in the defense ecosystem.[166]

Growth in advanced science and engineering degrees shows the U.S. graduating the largest number of doctorate recipients of any individual country, but 37% were earned by temporary visa holders[167] with as many 25% of STEM graduates in the U.S. being Chinese nationals.[168]

Case Studies: Workforce Sector Impacts on National Security

The skills gap affects a wide range of occupations and could have significant impacts on production of critical defense-related materials, vehicles, and machinery, as well as other goods and services necessary to supply our nation's armed forces. Examples include a lack of industrial machinery mechanics for motor vehicles, welders for surface and subsurface vehicles, and biophysicists for physiological sensor systems. In many of the traditional sectors, workforce issues were identified as key impacts – the below case studies merely add to that narrative.

Challenges to Recruit and Retain

Many companies in the industrial base recognize that significant skills gaps exist across multiple occupations, creating the potential to interfere with efficient acquisition of a wide variety of military equipment and other goods and services. Still more difficulties may be posed during a surge in defense production. A study by the Bureau of Industry and Security shows that companies with access to classified material – a potential indicator of a company's membership in the defense ecosystem – face significant workforce shortages. The review of

9,634 facilities found that 41% of the facilities cited labor availability/costs, 31% cited worker/skills retention, and 15% cited an aging workforce as concerns.[169]

Traditional vs Future Trade Skills

Although the number of workers engaged in many traditional production occupations, such as assemblers, machine setters, and mold makers, is projected to continue to decline over the coming decade, several other occupations that enable and support the modern, automated manufacturing facility are expected to surge. Occupations expected to grow often require the technical skills to program, maintain, troubleshoot, and repair increasingly sophisticated production machinery. For example, the number of computer-controlled machine operators and programmers are projected to grow by more than 17% by 2024, adding an additional 25,000 operators and more than 4,000 programmers. The number of machinists needed to set up and repair machine tools is expected to reach 343,200 nationwide by 2024, a 7.8% increase over 2014 employment levels. An expected 13.2% increase in industrial machinery mechanics would increase the ranks of such workers to nearly 201,000 nationwide over the next decade. And while the number of industrial production managers is expected to shrink through 2024, 55,500 replacement workers with appropriate skills will be needed to fill existing positions.

The Bureau of Labor Statistics projects that STEM jobs will see an increase of 962,000 jobs by 2026. This 11% increase is much higher than the average occupational rate increase, which is expected to be 7.4% between 2016 and 2026.[170]

Security Clearances

Ongoing challenges face DoD and its suppliers in getting personnel cleared to work on classified projects or in classified spaces. Concerns about the integrity of the investigation process coupled with diminished resources have created an ever growing backlog of employees waiting for clearances. However, a major effort is underway to address the issue. Pursuant to the National Defense Authorization Act for FY 2018, DoD recently stood up the Defense Vetting Directorate within the Defense Security Service. The newly announced directorate will oversee the creation and execution of a comprehensive personnel vetting strategy, to renew the entire personnel security clearance process. As part of streamlining efforts, the directorate will utilize the National Background Investigative System, which will include automated records checks as well as risk assessment protocols and other capabilities. The system will be founded on advanced analytics and sounds risk assessment to serve as key capabilities, ensuring a timely, trustworthy, loyal, and reliable workforce clearance process.

This page intentionally blank.

Appendix Three: Contributing U.S. Government Agencies

Department of Defense

Air Force (USAF)

- Air Combat Command (ACC)
  - Warfare Center (USAFWC)
- Air Staff (AF)
  - Strategic Plans and Programs (AF/A5/8)
    - Air Reserve Assessments Division (A5SM)
- Materiel Command (AFMC)
  - Life Cycle Management Center (LCMC)
  - Research Laboratory (AFRL)
    - Electronics and Sensors Branch (RXME)
    - Materials (Materials)

- Technical Engineering Services Directorate (EZAD)

- Secretary of the Air Force (SAF)
  - Office of the Assistant Secretary of the Air Force for Acquisition, Technology & Logistics (AQ)
    - Logistics and Product Support (AQD)
    - Missiles and Munitions Program Element Monitor (M&M PEM)
  - Space Command (AFSPC)
    - Space and Missile Systems Center (SMC)

Army (USARMY)

- Headquarters (HQDA)
  - Logistics Directorate (HQDA G-4)
- Intelligence and Security Command (INSCOM)
  - National Ground Intelligence Center (NGIC)
- Materiel Command (AMC)
  - Chemical Materials Activity (CMA)
  - Chief Information Officer – Information Assurance (CIO-IA)
  - Joint Munitions Command / Joint Munitions and Lethality Life Cycle Management Command (JMC/JM&L)
  - Research, Development and Engineering Command (RDECOM)
    - Armament Research, Development and Engineering Center (ARDEC)
    - Aviation and Missile Research Development and Engineering Center (AMRDEC)
    - Communications-Electronics Research, Development and Engineering Center (CERDEC)
      - Intelligence and Information Warfare Directorate (I2WD)
    - Contracting Command (ACC)
      - Aberdeen Proving Ground Plans, Analysis, and Integration Office (APG PAIO)
    - Edgewood Chemical Biological Center (ECBC)
    - Natick Soldier Systems Center (NSSC)
    - Research Laboratory (ARL)
  - Tank-Automotive and Armaments Command (TACOM)
    - Life Cycle Management Command (LCMC)
      - Materiel Systems Organization (MSO)
      - Integrated Logistics Support Center (ILSC)
        - Chemical / Biological Defense Product Support Integration Directorate (Chem/Bio PSID)

- Office of the Assistant Secretary of the Army for Acquisition, Logistics & Technology (ASA (ALT))
  - Joint Program Executive Office for Chemical Biological Defense (JPEO CBD)
  - PEO Ground Combat Systems (GCS)
  - PEO Missiles and Space
  - PEO Soldier

Defense Contract Management Agency (DCMA)

- Industrial Analysis Group (IAG)

Defense Intelligence Agency (DIA)

Defense Logistics Agency (DLA)

- Acquisitions
  - Strategic Sourcing

Joint Chiefs of Staff (JCS)

- Strategic Plans & Policy (J5)

Marine Corps

- Headquarters (HQMC)
  - Installations and Logistics (DC, I&L)
- Logistics Command (LOGCOM)
- Systems Command (MARCORSYSCOM)
  - PEO Land Systems (LS)
    - Ground Air Task Oriented Radar (G/ATOR)

Massachusetts Institute of Technology Lincoln Laboratory (MITLL)

Missile Defense Agency (MDA)

- Electronic Counter-Measures (ECM)
- Office of the Assistant Director for Assurance Integration
  - Quality, Safety, and Mission Assurance (QS)
- Office of the Director of Engineering (DE)

National Reconnaissance Office (NRO)

- Advanced Systems & Technology Directorate (AS&T)
- Systems Engineering Directorate (SED)

Navy (USN)

- Office of the Chief of Naval Operations (OPNAV)
  - Office of the Assistant Secretary of the Navy for Research, Development, and Acquisition (ASN(RDA))

- Deputy Assistant Secretary of the Navy for Air Programs (DASN AIR)
- DASN for Ships (DASN SHIPS)
- PEO for Integrated Warfare Systems (IWS)
  - Rotating Radar Program Office (2R1E)
- Naval Air Systems Command (NAVAIR)
- Naval Sea Systems Command (NAVSEA)
  - Naval Surface Warfare Center – Crane (NSWC Crane)
  - Naval Surface Warfare Center – Dahlgren (NSWC Dahlgren)

Office of the Secretary of Defense (OSD)

- Office of the Under Secretary for Acquisition and Sustainment (A&S)
  - Logistics and Materiel Readiness (L&MR)
    - Office of the Deputy Assistant Secretary of Defense for Supply Chain Integration (SCI)
    - Office of the Deputy Assistant Secretary of Defense for Maintenance Policy and Programs (MPP)
  - Office of the Deputy Assistant Secretary of Defense for Industrial Policy (IndPol)
  - Office of the Assistant Secretary of Defense for Acquisition (ASD(A))
    - Office of Space, Strategic, and Intelligence Systems (SSI)
      - Ground-Based Strategic Deterrent (GBSD)
      - Long Range Strike Office (LRSO)
      - Military Satellite Communication (MILSATCOM)
      - Missile Defense
      - NRO Systems
      - Space-Based Infrared System
- Office of the Under Secretary for Research and Engineering (R&E)
  - Office of Systems Engineering (DASD SE)
- United States Special Operations Command (USSOCOM)
- Defense Microelectronics Activity (DMEA)
- Defense Security Service (DSS)

Central Intelligence Agency (CIA)

Department of Commerce (DOC)

- Bureau of Industry and Security (BIS)
  - Office of Technology Evaluation (OTE)
  - Office of the Deputy Assistant Secretary for Export Administration

- International Trade Administration (ITA)
  - Office of the Deputy Assistant Secretary for Manufacturing
- National Institute of Standards and Technology (NIST)
  - Industry & Innovation Services (I&IS)
    - Manufacturing Extension Partnership (MEP)

Department of Energy (DOE)

- National Nuclear Security Administration (NNSA)
- Office of Energy Efficiency and Renewable Energy (EERE)
  - Advanced Manufacturing Office (AMO)
- Office of Environmental Management (EM)
  - Chief of Nuclear Safety (CNS)
  - Los Alamos National Laboratory (LANL)
- Office of Science
  - Oak Ridge National Laboratory (ORNL)

Department of Health and Human Services (HHS)

- Office of the Assistant Secretary for Preparedness and Response (ASPR)
- Office of the Senior Counselor to the Secretary

Department of Homeland Security (DHS)

- Office of Trade and Transportation Policy

Department of the Interior (DOI)

- United States Geological Survey (USGS)

Department of Labor (DOL)

- Office of the Assistant Secretary for Administration and Management (OASAM)
- Office of the Assistant Secretary for Policy (OASP)

Department of State (DOS)

- Policy Planning Staff (S/P)

Department of the Treasury (DOT)

- Office of International Affairs

International Trade Commission (ITC)

National Aeronautics and Space Administration (NASA)

National Science Foundation (NSF)

- National Center for Science and Engineering Statistics

National Security Agency (NSA)

Office of the Director of National Intelligence (ODNI)

- National Counterintelligence and Security Center (NCSC)

White House / Executive Office of the President (WH/EOP)

- National Security Council (NSC)
  - Director for International Trade and Investment
  - Director for Nonproliferation and Strategic Trade
- Office of Management and Budget (OMB)
  - National Security Division
    - Defense Science and Technology Examiner
- Office of Policy Development
  - Domestic Policy Council
  - National Economic Council (NEC)
    - Director for International Economic Affairs
- Office of Science and Technology Policy (OSTP)
- Office of Trade and Manufacturing Policy (OTMP)

Non-U.S. Government Organizations

- ANSER
- Institute for Defense Analyses (IDA)
- Manufacturing USA NextFlex Institute

Appendix Four: U.S. Government Sources

Department of Defense

Air Force (AF)

- Air Force Annual Industrial Base Assessment
- Air Force ManTech AESA Radar Roadmap: A Sub-Tier Industrial Base Perspective
- Air Force Research Laboratory (AFRL)
  - Sustainment Overview
  - AFRL Materials and Manufacturing Directorate Electronics and Sensors Branch (RXME)
    - Industrial Base Assessment Aerospace Applications for Carbon Nanotubes
    - Industrial Base Assessment AESA Suppliers – Market Survey and Issues
    - Industrial Base Assessment APG-68(V)9/(V)10 and APS-143G(V)1 Radar Systems
    - Industrial Base Assessment KC-46 Supplier Chain Risk Assessment
    - Industrial Base Assessment Multifunctional Materials Assessment

  - Industrial Base Assessment North American Military and Commercial Engine Assessment
  - Industrial Base Assessment Remotely Piloted Aircraft
  - Industrial Base Assessment Three-Dimensional Expeditionary Long-Range Radar Sub-tier Supplier Industrial Base Potential Issues
  - Industrial Base Assessment Unmanned Systems Integrated Roadmap, FY2013-2038
  - Industrial Base Assessment Update to AESA Suppliers – Market Survey and Issues
- Capital Investment Study on Air Force Depots

Army (USARMY)

- Aerospace Casting Study
- Aerospace Composite Analysis
- Analysis of H-47 Supply Chain Risks
- Armed Scout Helicopter Divestiture Industrial Base Report
- Aviation and Missile Research Development and Engineering Center (AMRDEC)
  - Aerospace Bearing Industry Sector Analysis
  - Puma/Raven Unmanned Aircraft System (UAS) Supplier Analysis
- Avionics Sector Analysis
- B-52H Re-engine Alternate Supplier Market Research
- Body Armor Working Group Data
- CH-47 Block II Analysis of Alternatives Industrial Capabilities Assessment
- Defense Industrial Base E-Repository
- Gray Eagle Industrial Capabilities Assessment
- Industrial Base Baseline Assessments
- Industrial Base Data Warehouse
- Missile and Aviation Supply Chain Operations Tool
- Program Executive Officer Ground Combat Systems (PEO GCS)
  - Industrial Base Considerations for Increased Vehicle Production to the Chief of Staff of the Army
- Rotorcraft Engine Industrial Base Sector Analysis
- Rotorcraft Forging Industrial Base Sector Analysis
- Specialty Steel Sector Analysis
- Supplier Risk Tracker
- Tank-Automotive and Armaments Command (TACOM)
  - Industrial Base Baseline Assessment
    - UAS Sector Analysis

Defense Contract Management Agency (DCMA)

- A-10 Wing Replacement Program Rate Analysis

- Active Electronically Scanned Array (AESA) Design Skills Assessment Report
- Annual Aircraft Industry Economic Forecast Assessment
- eTools Delegation Data
- eTools Industrial Base Integrated Data System
- eTools Supplier Risk System
- Ground Combat Systems Manufacturing Capacity Assessment
- Industrial Analysis Center Tactical Airborne AESA Radar White Paper
- Industrial Capabilities Assessment: Advance Digital Data Set
- Industrial Capabilities Assessment: Advanced Airborne Sensor
- Industrial Capabilities Assessment: Aircraft Sector
- Industrial Capabilities Assessment: Body Armor
- Industrial Capabilities Assessment: BQM-177A Subsonic Aerial Target
- Industrial Capabilities Assessment: CH-53K King Stallion
- Industrial Capabilities Assessment: F-35 Long Lead Material Supplier Assessment
- Industrial Capabilities Assessment: Future Vertical Lift
- Industrial Capabilities Assessment: Infrared Search and Track System (F-18)
- Industrial Capabilities Assessment: Microwave Tube
- Industrial Capabilities Assessment: MQ-1C Gray Eagle UAS
- Industrial Capabilities Assessment: MQ-4C Triton UAS
- Industrial Capabilities Assessment: MQ-4C Triton UAS Addendum
- Industrial Capabilities Assessment: MQ-8 Fire Scout UAS
- Industrial Capabilities Assessment: Multi-Spectral Camouflage Netting
- Industrial Capabilities Assessment: Next Generation Jammer
- Industrial Capabilities Assessment: Night Vision
- Industrial Capabilities Assessment: Parachutes
- Industrial Capabilities Assessment: RQ-21A Integrator Small Tactical Unmanned Aircraft System
- Industrial Capabilities Assessment: Small Arms
- Infrared Decoy Industrial Base Assessment
- Military Rotary Wing Design and Engineering Capabilities Assessment
- Munitions Industry Production Analysis Report

Defense Logistics Agency (DLA)

- Casting Industry Assessment
- Defense Strategic and Critical Materials Operations Report To Congress
- Fragility and Criticality Assessments Army Robotics
- Fragility and Criticality Assessments Body Armor
- Fragility and Criticality Assessments Critical Energetic Materials
- Fragility and Criticality Assessments F-18

- Fragility and Criticality Assessments F-22 (Sustainment)
- Fragility and Criticality Assessments Fixed Wing Aircraft
- Fragility and Criticality Assessments Focal Plane Arrays
- Fragility and Criticality Assessments Gray Eagle
- Fragility and Criticality Assessments Ground Combat Systems
- Fragility and Criticality Assessments Ground Robotics
- Fragility and Criticality Assessments Ground Vehicles
- Fragility and Criticality Assessments Military Satellite Communications Systems
- Fragility and Criticality Assessments Navy Shipbuilding
- Fragility and Criticality Assessments Radar
- Fragility and Criticality Assessments Rotary Wing
- Fragility and Criticality Assessments Space
- Fragility and Criticality Assessments Tobyhanna Army Depot Skills
- Fragility and Criticality Assessments Vertical Lift Design Skills
- Fragility and Criticality Assessments Warfighter Information Network-Tactical Increment 1
- Steel & Specialty Metals Pricing Analysis

Missile Defense Agency

- Fragility and Criticality Assessments Missile Seekers
- Fragility and Criticality Assessments Missiles

Navy (USN)

- Naval Air Systems Command (NAVAIR)
  - Military Aviation Industrial Base Review (Tactical Aircraft Design)
  - Supplier Database
  - Tactical Combat Training System Analysis
- Naval Sea Systems Command (NAVSEA)
  - Rare Earth Metals & Usage in Microwave Tubes Briefing

Office of the Secretary of Defense (OSD)

- Annual Aviation Inventory and Funding Plan, FY 2017-2046
- Annual Industrial Capabilities Report to Congress FY2013
- Annual Industrial Capabilities Report to Congress FY2014
- Annual Industrial Capabilities Report to Congress FY2015
- Annual Industrial Capabilities Report to Congress FY2016
- Annual Industrial Capabilities Report to Congress FY2017
- Annual Industrial Capabilities Report to Congress FY2018
- Critical Energetic Materials Working Group Data
- Defense Innovation Unit Experimental (DIUx)

  - Defense Innovation Capital
- F-16 AESA Radar Upgrade Acquisition Strategy Paper
- Federal Procurement Data System
- Fuze Integrated Product Team Data
- Joint Industrial Base Working Group Data
- Industrial Policy (IndPol)
  - Body of Knowledge Electronic Warfare
  - Body of Knowledge Fixed Wing Aircraft
  - Body of Knowledge Rotary Wing Aircraft
  - Body of Knowledge UAS
  - Identifying and Mitigating the Impact of the Budget Control Act on High Risk Sectors and Tiers of the Defense Industrial Base
  - Impact of the Budget Control Act on the Defense Industrial Base
  - Program Management Review Meeting Defense Production Act Title III Tungsten Rhenium Wire Production Sustainment Project
  - Proposed Acquisition of Sikorsky Aircraft by Lockheed Martin
- National Defense Strategy
- Nuclear Posture Review

Congressional Research Service

- China's Mineral Industry and U.S. Access to Strategic and Critical Minerals: Issues for Congress
- Rare Earth Elements in National Defense: Background, Oversight Issues, and Options for Congress
- The Buy American Act—Preferences for "Domestic" Supplies: In Brief
- The Specialty Metal Clause: Oversight Issues and Options for Congress

Department of Commerce

- Bureau of Industry and Security (BIS)
  - Cost-Metric Assessment of Diminishing Manufacturing Sources and Material Shortages
  - Critical Facilities Survey Data
  - Critical Technology Assessment: Fine Grain, High-Density Graphite
  - Critical Technology Assessment: Impact of U.S. Export Controls on Green Technology Items
  - Critical Technology Assessment: Night Vision Focal Plane Arrays, Sensors, and Cameras
  - Cybersecurity Framework Manufacturing Profile
  - Defense Industrial Base Assessment of Counterfeit Electronics

  - Defense Industrial Base Assessment of Rocket Propulsion
  - Defense Industrial Base Assessment of the Telecommunications Industry Infrastructure
  - Defense Industrial Base Assessment of the U.S. Underwater Acoustics Transducer Industry
  - Defense Industrial Base Assessment of U.S. Textiles, Apparel, and Footwear
  - Framework for Improving Critical Infrastructure Cybersecurity
  - Industrial Base Assessment of Consumers of U.S. Electro-Optical Satellite Imagery
  - National Aeronautics and Space Administration's (NASA) Human Space Flight Industrial Base in the Post-Space Shuttle/Constellation Environment
  - National Security Assessment of the C-17 Globemaster Cargo Aircraft's Economic & Industrial Base Impacts
  - National Security Assessment of the Cartridge and Propellant Actuated Device Industry: 4th Review
  - Reliance on Foreign Sourcing in the Healthcare and Public Health Sector: Pharmaceuticals, Medical Devices, and Surgical Equipment
  - Sector to Sector, Tier to Tier Data
  - The Effect of Imports of Aluminum on the National Security, an Investigation Conducted under Section 232 of the Trade Expansion Act of 1962, as Amended
  - The Effect of Imports of Steel on the National Security, an Investigation Conducted under Section 232 of the Trade Expansion Act of 1962, as Amended
  - U.S. Bare Printed Circuit Board Supply Chain Assessment
  - U.S. Integrated Circuit Design and Fabrication Capability
  - U.S. Space Industrial Base "Deep Dive" Assessment: Employment in the U.S. Space Industrial Base
  - U.S. Space Industrial Base "Deep Dive" Assessment: Impact of U.S. Export Controls on the Space Industrial Base
  - U.S. Space Industrial Base "Deep Dive" Assessment: Small Businesses in the Space Industrial Base
  - U.S. Strategic Material Supply Chain Assessment: Carbon Fiber Composites
  - U.S. Strategic Material Supply Chain Assessment: Select Rare Earth Elements
  - U.S. Strategic Material Supply Chain Assessment: Titanium
- National Institute of Standards and Technology (NIST)
  - National Institute of Standards and Technology (NIST) Manufacturing Extension Partnership Cybersecurity Self-Assessment Handbook For Assessing NIST SP 800-171 Security Requirements in Response to Defense Federal Acquisition Regulations Cybersecurity Requirements

Department of Energy

- Critical Materials Strategy

Department of the Interior

- Managing Materials for a Twenty-First Century Military
- Mineral Commodity Summaries
- U.S. Geological Survey Data and Reports

Department of Labor

- Bureau of Labor Statistics Data

Government Accountability Office

- Defense Supply Chain: The Department of Defense Needs Complete Information on Single Sources of Supply to Proactively Manage the Risks
- Nuclear Weapons: The National Nuclear Security Administration Needs to Determine Critical Skills and Competencies for Its Strategic Materials Programs

Joint Army Navy NASA Air Force Interagency Propulsion Committee

- Bi-Annual Propulsion Industrial Sector Integrated Program Plan and Key Decision Points

White House / Executive Office of the President

- National Security Strategy
- Office of Trade & Manufacturing Policy (OTMP)
    - China's Strategies of Economic Aggression: How China Threatens the Intellectual Property and Technologies of America and the World

U.S. Government-Sponsored Sources

- A.T. Kearney Combat Vehicle Industrial Base Study
- Institute for Defense Analyses (IDA) Assessment Activities for Industrial Policy in Support of Executive Order 13806
- IDA Munitions Resilience Study
- MFORESIGHT America's Next Manufacturing Workforce
- MFORESIGHT Cybersecurity for Manufacturers
- MFORESIGHT Democratizing Manufacturing
- MFORESIGHT Ensuring American Manufacturing Leadership Through Next-Generation Supply Chains
- MFORESIGHT Metamaterials Manufacturing

This page intentionally blank.

Appendix Five: Industry Listening Sessions

The below list includes the industry listening sessions the Interagency Task Force conducted. Many of the sessions were hosted and facilitated by trade associations, allowing the working groups a breadth of industry representatives in one meeting.

Date	Host	Session Title	Sector(s) Addressed
Dec. 15, 2017	National Defense Industrial Association	Industry Listening Session	Electronics
Jan. 22, 2018	Center for Strategic and International Studies	Charting a New Course for the Industrial Base	Macro forces
Jan. 25, 2018	Association for Manufacturing Technology and Georgia Tech Global Learning Center	AMT Machine Tools Data Gathering Workshop	Machine Tools
Jan. 26, 2018	Association for Manufacturing Technology	Advanced Manufacturing Workshop	Machine Tools

Date	Host	Session Title	Sector(s) Addressed
Jan. 31, 2018	Professional Services Council	Leadership Summit	Workforce
Feb. 7, 2018	Cowen Inc.	Aerospace and Defense Conference	Macro forces
Feb. 8, 2018	University of California San Diego 21st Century China Center	New Approaches to Reviewing and Regulating Chinese High Tech Investment	Macro forces
Mar. 1, 2018	National Defense University	Foundation Breakfast Briefing	Macro forces
Mar. 7, 2018	National Institute of Standards and Technology Manufacturing Extension Program	Advisory Board Meeting	Macro forces
Mar. 20, 2018	Precision Strike Association	Annual Review	Munitions & Missiles
Mar. 28, 2018	Aerospace Industries Association	Industry Listening Session	Aircraft
Mar. 28, 2018	Aerospace Industries Association	Industry Listening Session	Space
Mar. 29, 2018	Aerospace Industries Association	Industry Listening Session	Munitions & Missiles
Mar. 29, 2018	Aerospace Industries Association	Industry Listening Session	Radar & EW
Apr. 3, 2018	National Defense Industrial Association	Industry Listening Session	Ground Systems

Critical to the cybersecurity working group efforts were a series of nearly thirty sessions hosted by the National Institute of Standards and Technology Manufacturing Extension Partnership program from January - December 2017. Many of the sessions, which were conducted in over twenty states and reached over 1,000 U.S. manufacturers, included participation from DoD Procurement Technical Assistance Centers. The sessions familiarized small and medium size companies with the DFARS requirement to ensure adequate cybersecurity protections are in place by implementing the security controls contained in NIST SP 800-171. Direct personal interactions that occurred during the sessions regarding the challenges small and medium manufacturers face in terms of defensive and offensive cybersecurity, informed the cybersecurity in manufacturing working group's inputs and recommendations as part of the EO 13806 effort.

Appendix Six: Agreements with Foreign Governments

Security of Supply Agreements

DoD has entered into arrangements with several nations to ensure the mutual supply of defense goods and services. These bilateral Security of Supply arrangements allow the DoD to request priority delivery for DoD contracts, subcontracts, or orders from companies in these countries. Similarly, the arrangements allow the signatory nations to request priority delivery for their contracts and orders with U.S. firms.

Conducted under the overarching Declarations of Principles for Enhanced Cooperation in Matters of Defense Equipment and Industry that have been signed with certain nations, Security of Supply arrangements implement the "Meeting National Defense Requirements" section. The arrangements recognize the potential for a certain degree of mutual interdependence of supplies needed for national security, and calls for the parties to explore solutions for achieving assurance of supply. Reciprocal industrial priority systems encourage partner nations to acquire

defense goods from each other, promote interoperability, and provide assurance of timely delivery during peacetime, emergency, and armed conflict.

The following countries are party to Security of Supply agreements with the United States: Australia, Canada, Finland, Italy, Netherlands, Norway, Spain, Sweden, and the United Kingdom.[171]

Cooperative International Agreements

DOD has a highly structured process governing the development, negotiation, coordination, and implementation of cooperative international agreements:

- Memoranda of Understanding;
- Memoranda of Agreement;
- Projects Agreements and Arrangements; and
- Equipment and Material Transfer Arrangements

International agreements are used to establish information exchanges; personnel exchanges and assignments; cooperative research, development, test and evaluation projects; cooperative acquisitions; cooperative production (including licensed coproduction); or cooperative or reciprocal logistics support.

Any international agreement between the U.S. and another nation constitutes a commitment binding in international law on the part of the U.S. and the foreign government. The agreements obligate both governments to commit resources – funds, equipment, labor, information, or action – and outline the authorization and approval process to ensure the U.S. only commits to a course of action that is implementable and in its best interest.

Reciprocal Defense Procurement Agreements

Title 19, U.S. Code, Section 2512(a) directs the President to prohibit the procurement of foreign products from any country that is not a party to the Trade Agreements Act of 1979, so as to provide appropriate reciprocal competitive government procurement opportunities to U.S. products and suppliers of U.S. products. Title 19, U.S. Code, Section 2512(b) allows the President to authorize the Secretary of Defense to waive the prohibition on procurement of foreign products of any country that enters into a reciprocal procurement agreement with DoD. A Reciprocal Defense Procurement agreement is an example of such an agreement.

Under a Reciprocal Defense Procurement agreement, countries afford each other certain benefits on a reciprocal basis, consistent with their national laws and regulations. Each Reciprocal Defense Procurement agreement provides a framework for ongoing communication between or among DoD and its respective counterparts regarding market access and procurement matters that contribute to effective defense cooperation. Key Reciprocal Defense

Procurement agreement principles include: fair competition, reduced market barriers, transparent processes, and protection of intellectual property.

The authority to conclude a Reciprocal Defense Procurement agreement is found at Section 2531 of Title 10, U.S. Code. A country that has concluded a Reciprocal Defense Procurement agreement with DoD is termed a "qualifying country" in the DoD Federal Acquisition Regulation Supplement.[172] The DoD has Reciprocal Defense Procurement agreements in effect with the following 27 countries: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Egypt, Estonia, Finland, France, Germany, Greece, Israel, Italy, Japan, Latvia, Luxembourg, Netherlands, Norway, Poland, Portugal, Slovenia, Spain, Sweden, Switzerland, Turkey, and the United Kingdom.

Reciprocal Government Quality Assurance Agreement

Paragraph (h) of Section 2761 of title 22, U.S. Code, provides the legal authority for an agreement for the performance of quality assurance services on a reciprocal no-charge basis between DoD and its counterparts for any contract or subcontract for defense articles, defense services, or design and construction services. Government Quality Assurance agreements promote the use of common quality assurance standards and protocols whereby each government supports purchases of defense equipment from its industry by the other government, and by defense contractor performing work for the other government. Such agreements help promote the interoperability and standardization of conventional defense equipment used by the U.S. Armed Forces and the partner's armed forces, and facilitate cooperation between our defense industries.

Government Quality Assurance agreements take either the form of a Government Quality Assurance annex to the Reciprocal Defense Procurement agreement that DoD has with the partner government, or as a stand-alone document. DoD has Government Quality Assurance agreements with the following 21 countries: Australia, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Israel, Italy, Republic of Korea, Netherlands, Norway, Poland, Romania, Spain, Slovakia, Sweden, Turkey, and the United Kingdom.[173]

This page intentionally blank.

Photo Credits

Page	Credit
Cover	iStock
1	Photo by John Snyder, Watervliet Arsenal https://www.dvidshub.net/image/4155302/arsenals-new-contract-will-increase-soldiers-safety-artillery-range
7	U.S. Air Force photo by Justin Connaher, Joint Base Elmendorf-Richardson Public Affairs https://www.dvidshub.net/image/4419918/making-pointy-end
11	Courtesy photo by the Defense Contract Management Agency https://www.dvidshub.net/image/2173960/fort-worth-seeks-substantial-return-keystone-investment
15	U.S. Air Force photo by Tommie Horton, 78th Air Base Wing Public Affairs https://www.dvidshub.net/image/2084946/cmxg-working-toward-achieving-art-possible
19	U.S. Air Force photo by Senior Airman Quay Drawdy, 18th Wing Public Affairs https://www.dvidshub.net/image/4669278/pretty-heavy-metal
45	U.S. Army photo by Debralee Best, Rock Island Arsenal – Joint Manufacturing and Technology Center (RIA-JMTC) https://www.dvidshub.net/image/3770282/ria-jmtc-tests-new-pour-basin

Page	Credit
53	U.S. Marine Corps photo by Staff Sgt. Britni M. Garcia Green, U.S. Marine Corps Force, Europe and Africa https://www.dvidshub.net/image/4560212/spmagtf-cr-af-moves-towards-3d-printing
59	U.S. Air Force photo by Wesley Farnsworth, 88th Air Base Wing Public Affairs https://www.dvidshub.net/image/2331085/wpafb-office-saves-department-defense-millions
63	U.S. Navy photo by Mass Communication Specialist 1st Class Richard Doolin https://www.dvidshub.net/image/4516730/180618-n-ox597-031
64	U.S. Navy photo by Mass Communication Specialist 3rd Class Alex Corona, USS Theodore Roosevelt https://www.dvidshub.net/image/4229024/uss-theodore-roosevelt-cvn-71-deployment-fy-2018
67	U.S. Air Force Photograph by Donna L. Burnett, Maxwell Air Force Base Public Affairs https://www.dvidshub.net/image/3187713/maxwell-cbrne-exercise
69	U.S. Army photo by Visual Information Specialist Getrud Zach https://www.dvidshub.net/image/3690808/1st-battalion-8th-infantryregiment-calfex
71	U.S. Marine Corps photo by Lance Cpl. Cody J. Ohira https://www.dvidshub.net/image/3855061/2nd-laad-stinger-range
73	U.S. Air Force photo by Airman 1st Class Braydon Williams, 90th Missile Wing Public Affairs https://www.dvidshub.net/image/4204337/missile-maintainers-tear-down-icbm-maintenance
75	U.S. Navy photo by Mass Communication Specialist Seaman Vance Hand https://www.dvidshub.net/image/3833040/uss-america-sailor-mans-radar-terminal
78	U.S. Navy photo by Petty Officer 2nd Class Kihlo Park https://www.dvidshub.net/image/287557/uss-harry-s-truman-passes-gibraltar-takes-supplies
81	U.S. Marine Corps photo by Pfc. Melanye Martinez, 2nd MARDIV, Combat Camera https://www.dvidshub.net/image/1826576/2d-mardiv-headquarters-battalion-9-mile-hike
84	U.S. Air Force courtesy photo by United Launch Alliance https://www.dvidshub.net/image/3241843/wgs9-launch
87	Photo by Petty Officer 2nd Class Nathaniel Moger, Joint Task Force Guantanamo Public Affairs https://www.dvidshub.net/image/103088/information-assurance-cyber-defenders
89	U.S. Air Force courtesy photo, Air Force Research Laboratory https://www.dvidshub.net/image/4046791/afrl-american-semiconductor-create-flexible-system-chip-internet-things
92	Photo by John Snyder, Watervliet Arsenal https://www.dvidshub.net/image/3670607/army-apprentices-experiencing-best-most-difficult-years-their-lives
94	Photo by Debralee Best, Rock Island Arsenal – Joint Manufacturing and Technology Center (RIA-JMTC) https://www.dvidshub.net/image/3794962/ria-jmtc-produces-production-aid-depot
96	U.S. Army Engineering and Support Center photo, Huntsville Public Affairs Office http://www.hnc.usace.army.mil/Media/News-Releases/Article/588223/project-underway-to-upgrade-heating-system-at-rock-island-arsenal/
99	Photo by James Lentz, Tobyhanna Army Depot https://www.dvidshub.net/image/3962789/tobyhanna-assists-testing-encryption-solution
101	Photo by Hayley Smith, Crane Army Ammunition Activity https://www.dvidshub.net/image/4098633/crane-army-produces-practice-rounds-fleet

Page	Credit
105	U.S. Marine Corps photo by Cpl. Joseph Sorci https://www.defense.gov/Photos/Photo-Gallery/igphoto/2001873640/
111	U.S. Navy photo by Lt. David Babka https://www.dvidshub.net/image/4090662/180120-n-zz999-0002
119	U.S. Marine Corps photo by Marines Corps photo by Lance Cpl. Brennon A. Taylor, 2nd Marine Division https://www.dvidshub.net/image/4108812/charlie-company-2d-reconnaissance-battalion-dive-insertion-training-key-west
121	U.S. Army photo by Gertrud Zach https://dod.defense.gov/Photos/Photo-Gallery/igphoto/2001894477/
125	U.S. Marine Corps Photo by Lance Cpl. Jamin M. Powell, 3rd Marine Logistics Group https://www.dvidshub.net/image/4541411/practice-makes-perfect
129	U.S. Air Force photo by Tech. Sgt. Gregory Brook, U.S. Air Force Central Command Public Affairs https://www.dvidshub.net/image/4201092/83rd-erqs-guardian-angels-conduct-tactical-critical-casualty-care-working-with-us-army-ch-47s

This page intentionally blank.

Endnotes

[1] President Donald Trump, Executive Order 13806, July 2017. https://www.whitehouse.gov/presidential-actions/presidential-executive-order-assessing-strengthening-manufacturing-defense-industrial-base-supply-chain-resiliency-united-states/

[2] National Security Strategy of the United States, December 2017. https://www.whitehouse.gov/wp-content/uploads/2017/12/NSS-Final-12-18-2017-0905.pdf

[3] 2018 National Defense Strategy of the United States of America, January 2018, pg. 2. https://www.defense.gov/Portals/1/Documents/pubs/2018-National-Defense-Strategy-Summary.pdf

[4] National Science Foundation, "Science and Engineering Indicators, 2018," 2018.

https://www.nsf.gov/statistics/2018/nsb20181/digest/sections/u-s-and-global-stem-education

[5] President Donald Trump, Executive Order 13806, July 2017. https://www.whitehouse.gov/presidential-actions/presidential-executive-order-assessing-strengthening-manufacturing-defense-industrial-base-supply-chain-resiliency-united-states/

[6] The Interagency Task Force determined the assessment would focus on the capabilities needed for the "fight tonight," thus scoping the effort to the nine traditional and six cross-cutting sectors outlined in Figure 1. The Interagency Task Force and the Office of Trade and Manufacturing Policy agreed early on that the most effective way to approach the task was to scope the first effort for the fight tonight and conduct follow-on efforts to assess manufacturing and defense industrial base needs for a great power conflict scenario, as well as evaluating next generation technologies for future threats. The classified Action Plan provides descriptions of follow-on efforts.

[7] In their study supporting the Industrial Policy Office, the Defense Science Board listed the following as components of the defense industrial base: for-profit companies, not-for-profit companies, universities and associated university-affiliated research centers, federally-funded research and development centers, and the open-source community that provides both hardware and software.

[8] W. L. Mackenzie King, Hyde Park Declaration, April 1941. http://wartimecanada.ca/sites/default/files/documents/WLMK.HydePark.1941.pdf

[9] FY2017 National Defense Authorization Act, Section 881. Greater Integration of the National Technology and Industrial Base.

[10] Despite these designations, National Technology and Industrial Base partners are subject to a variety of U.S. export control laws and regulations, except in those specific cases where exceptions or parallel structures have been established. The Canadian defense industry enjoys special exceptions to some of the most rigorous export control elements, including the International Traffic in Arms Regulations regime. Defense industry relations with the United Kingdom and Australia, however, are separately governed by preexisting Defense Trade Cooperation Treaties. Currently, DoD is developing a plan to reduce the barriers to the seamless integration across the National Technology and Industrial Base, as mandated by the FY2017 National Defense Authorization Act.

[11] Center for Strategic and International Studies, What the Continuing Resolution Means for Defense Spending in FY2018, September 27, 2017. https://www.csis.org/analysis/what-continuing-resolution-means-defense-spending-fy-2018

[12] In the 2011 Budget Control Act, Congress set budget limits known as sequestration. The deficit reduction sequester required nine annual sequesters of $109 billion – half from defense and half from non-defense programs – to reduce the deficit by $1.2 trillion. The first of these annual sequesters took effect in March 2013.

[13] Bradley Martin et al, A Strategic Assessment of the Future of U.S. Navy Ship Maintenance, RAND, 2017. https://www.rand.org/content/dam/rand/pubs/research_reports/RR1900/RR1951/RAND_RR1951.pdf

[14] The Naval Registry.

[15] Vehicle, missiles, and aircraft numbers derived from Service Property Book data repositories.

[16] Log Cost Baseline calculation.

[17] Maintenance and Availability Data Warehouse.

[18] Analysis of data from DoD Comptroller's Green Book.

[19] Center for Strategic and International Studies, Measuring the Impact of Sequestration and the Defense Drawdown on the Industrial Base, 2011-2015, 22 January 2018. https://www.csis.org/analysis/measuring-impact-sequestration-and-drawdown-defense-industrial-base

[20] Defense Production Act Title III.

[21] CNAS, A Brief History of Budget Instability, 2017. https://www.cnas.org/publications/reports/a-brief-history-of-defense-budget-instability, includes two additional CRs of December 2017 and January 2018.

[22] CSIS, "What a Continuing Resolution Means for Defense Spending," 2017. https://www.csis.org/analysis/what-continuing-resolution-means-defense-spending-fy-2018

[23] U.S. Government Accountability Office Report: *DOD Is Taking Steps to Address Challenges Faced by Certain Companies*, GAO-17-644, Washington, DC: Government Accountability Office, July 2017. https://www.gao.gov/assets/690/686012.pdf

[24] Sree Ramaswamy, et al., "Making it in America: Revitalizing U.S. Manufacturing," McKinsey Global Institute, November 2017. https://www.mckinsey.com/global-themes/americas/making-it-in-america-revitalizing-us-manufacturing

[25] National Security Strategy of the United States, December 2017. https://www.whitehouse.gov/wp-content/uploads/2017/12/NSS-Final-12-18-2017-0905.pdf

[26] Robert Atkinson, et al., "Worse Than the Great Depression: What Experts are Missing about American Manufacturing Decline," Information Technology & Innovation Foundation, March 2012. http://www2.itif.org/2012-american-manufacturing-decline.pdf

[27] Bureau of Labor Statistics, "Multifactor productivity slowdown in U.S. manufacturing." Monthly Labor Review, July 2018.

[28] Heather Long, "U.S. has lost 5 million manufacturing jobs since 2000," CNN Money, March 2016. http://money.cnn.com/2016/03/29/news/economy/us-manufacturing-jobs/index.html

[29] Data from the Bureau of Labor Statistics, U.S. Department of Labor, https://data.bls.gov/timeseries/CES3000000001.

[30] Joel Yudken, Ph.D., "Manufacturing Insecurity: America's Manufacturing Crisis and the Erosion of the U.S. Industrial Base," Cornell University ILR School, September 2010. https://digitalcommons.ilr.cornell.edu/cgi/viewcontent.cgi?referer=https://www.google.com/&httpsredir=1&article=1122&context=laborunions

[31] Center for Strategic and International Studies, "Measuring the Impact of Sequestration and the Drawdown on the Defense Industrial Base," 22 January 2018. https://www.csis.org/analysis/measuring-impact-sequestration-and-drawdown-defense-industrial-base

[32] Sree Ramaswamy, et al., "Making it in America: Revitalizing U.S. Manufacturing," McKinsey Global Institute, November 2017. https://www.mckinsey.com/global-themes/americas/making-it-in-america-revitalizing-us-manufacturing

[33] MForesight, "Ensuring American Manufacturing Leadership Through Next Generation Supply Chains," June 2017. http://mforesight.org/projects-events/supply-chains/

[34] *Ibid.*

[35] *Ibid.*

[36] Robert Atkinson, et al., "Worse Than the Great Depression: What Experts are Missing about American Manufacturing Decline," Information Technology & Innovation Foundation, March 2012. http://www2.itif.org/2012-american-manufacturing-decline.pdf

[37] Vaclav Smil, "The Rise and Retreat of American Manufacturing." The MIT Press. 2013.

[38] Lee Simmons, "Rare-Earth Market," *Foreign Policy,* July 12,2016. http://foreignpolicy.com/2016/07/12/decoder-rare-earth-market-tech-defense-clean-energy-china-trade/

[39] The 2017 National Security Strategy reclassified China as a "strategic competitor" that is engaged in "economic aggression." National Security Strategy of the United States, December 2017, pg. 45. https://www.whitehouse.gov/wp-content/uploads/2017/12/NSS-Final-12-18-2017-0905.pdf

[40] As an example of China's economic aggression, after effectively putting the sole rare earth mine in America out of business, China tried to buy the mine. Henry Sanderson. "Battle Heats Up for Control of Sole US Rare Earth Mine," *Financial Times,* 30 May 2017. https://www.ft.com/content/2c3dea3e-3fc2-11e7-82b6-896b95f30f58

[41] Keith Bradsher, "Amid Tension, China Blocks Vital Exports to Japan," *New York Times,* 22 September 2010. https://www.nytimes.com/2010/09/23/business/global/23rare.html

[42] Lok –Won Kim & John D. Villasenor, "A System-On-Chip Bus Architecture for Thwarting Integrated Circuit Trojan Horses," IEEE Transactions On VLSI Systems, Vol. 19, No. 10, pp. 1921-1926, October 2011. http://ieeexplore.ieee.org/xpl/login.jsp?tp=&arnumber=5556060

[43] National Research Council, "Rising to the Challenge: U.S. Innovation Policy for the Global Economy," The National Academies Press, 2012. https://doi.org/10.17226/13386

[44] *Ibid.*

[45] Steven Kline, Jr. "Understanding the Machine Tool Industry's Ups and Downs," *Modern Machine Shop Online*, https://www.mmsonline.com/articles/understanding-the-machine-tool-industrys-ups-and-downs, 1 May 2017.

[46] Gardner Research World Machine Tool Survey, 2016, p6. https://www.gardnerweb.com/articles/2016-world-machine-tool-survey

[47] Dashan Kalyani, "IBISWorld Industry Report 33351 Metalworking Machinery Manufacturing in the U.S.," September 2017, IBISWorld Inc.

[48] Randy Starr and William Lay, "2016 Aerospace and Defense Industry Trends." Strategy&, 11 March 2016. Accessed January 11, 2018. https://www.strategyand.pwc.com/trends/2016-aerospace-and-defense-industry-trends

[49] In full recognition of this challenge, one of the National Defense Strategy's lines of effort is reforming DoD's business practices for greater performance and affordability. To that end, DoD leadership is currently reviewing the Defense Acquisition University teaching model to determine a more effective and efficient way to educate and empower DoD's acquisition professionals to combat contracting barriers and inefficiencies across a broad spectrum of challenges.

[50] House Committee on Armed Services, *Challenges to Doing Business with the Department of Defense: Findings of the Panel on Business Challenges in the Defense Industry* (Washington, DC: U.S. Congress, March 2012).
https://wcoeusa.org/sites/default/files/Challenges%20to%20Bus%20with%20DOD.3.12.pdf

[51] Report of the Advisory Panel on Streamlining and Codifying Acquisition Regulations, Volume 1 of 3, January 2018.

[52] U.S. Government Accountability Office Report: *DOD Is Taking Steps to Address Challenges Faced by Certain Companies*, GAO-17-644, Washington, DC: Government Accountability Office, July 2017.
https://www.gao.gov/assets/690/686012.pdf

[53] Defense Business Board, *Innovation: Attracting and Retaining the Best of the Private Sector*, Washington, DC: Defense Business Board, 2014.
http://dbb.defense.gov/Portals/35/Documents/Reports/2014/DBB-FY14-02-Innovation%20report%20(final).pdf

[54] Federal Acquisition Regulation, 48 Code of Federal Regulations §§15 1997.
https://www.gpo.gov/fdsys/pkg/FR-1997-09-30/pdf/97-25666.pdf#page=7

[55] U.S. Government Accountability Office Report: *DOD Is Taking Steps to Address Challenges Faced by Certain Companies*, GAO-17-644, Washington, DC: Government Accountability Office, July 2017.
https://www.gao.gov/assets/690/686012.pdf

[56] David Tate, "Acquisition Cycle Time: Defining the Problem," IDA, October 2016.

[57] AMRDEC MORE Tool. https://www.amrdec.army.mil/amrdec/pdf/MORE%20Tool.pdf

[58] U.S. Government Accountability Office Report: *DOD Is Taking Steps to Address Challenges Faced by Certain Companies*, GAO-17-644, Washington, DC: Government Accountability Office, July 2017.
https://www.gao.gov/assets/690/686012.pdf

[59] Defense Security Cooperation Agency, "Fiscal Year 2017 Sales Total $41.93B," 28 November 2017.
http://www.dsca.mil/news-media/news-archive/fiscal-year-2017-sales-total-4193b

[60] U.S. Census Bureau data. https://www.census.gov/foreign-trade/balance/c0004.html

[61] U.S. Census Bureau data. https://www.census.gov/foreign-trade/balance/c5700.html

[62] U.S. Census Bureau data. https://www.census.gov/foreign-trade/balance/c0003.html

[63] Reuters, "Technical Textile Market Size, Share, Report, Analysis, Trends & Forecast to 2022," 10 May 2017. https://www.reuters.com/brandfeatures/venture-capital/article?id=5437

[64] Department of Commerce, Industrial Base Assessments: U.S. Textiles, Apparel, and Footwear, https://www.bis.doc.gov/index.php/other-areas/office-of-technology-evaluation-ote/industrial-base-assessments

[65] National Council of Textile Organizations, "U.S. Textile Industry," April 2018.

http://www.ncto.org/facts-figures/us-textile-industry/

[66] Department of Commerce, Industrial Base Assessments: U.S. Textiles, Apparel, and Footwear.

[67] World Trade Organization, "World Trade Statistical Review 2017," October 2017.

https://www.wto.org/english/res_e/statis_e/wts2017_e/wts17_toc_e.htm

[68] National Council of Textile Organizations, "U.S. Textile Industry."

[69] Department of Commerce, Industrial Base Assessments: U.S. Textiles, Apparel, and Footwear, 2017. https://www.bis.doc.gov/index.php/other-areas/office-of-technology-evaluation-ote/industrial-base-assessments

[70] As the National Security Strategy notes: "China is gaining a strategic foothold in Europe by expanding its unfair trade practices and investing in key industries, sensitive technologies, and infrastructure." National Security Strategy of the United States of America," December 2017, p. 47. https://www.whitehouse.gov/wp-content/uploads/2017/12/NSS-Final-12-18-2017-0905.pdf.

[71] For an analysis of China's strategy to capture leading industries, see Josh Wübbeke, Mirjam Meissner, Max J. Zenglein, Jaqueline Ives, and Björn Conrad, "Made in China 2025: The Making of a High-Tech Superpower and Consequences For Industrial Countries," Mercator Institute for China Studies, December 2016, p. 54. https://www.merics.org/sites/default/files/2017-09/MPOC_No.2_MadeinChina2025.pdf. See also the Office of Trade and Manufacturing Policy's report, "China's Strategies of Economic Aggression," January 2018.

[72] The World Bank Group, "Countries and Economies, China GDP," 2017. https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=CN

[73] Department of Defense, "Annual Report to Congress on the Military Power of the People's Republic of China," 12 July 2002, pg 1. https://www.globalsecurity.org/military/library/report/2002/d20020712china.pdf

[74] Department of Defense, "Annual Report to Congress on Military and Security Developments Involving the People's Republic of China 2017," May 2017, pg 66. https://www.defense.gov/portals/1/documents/pubs/2017_china_military_power_report.pdf

[75] State Council of the People's Republic of China, *Made in China 2025*, 8 May 2015, Staff translation.

[76] For discussion, see, for example, "China's Plan to Crush the U.S. Robotics Industry", *CNBC.Com,* 6 September 2017, https://www.cnbc.com/2017/09/06/chinas-blueprint-to-crush-the-us-robotics-industry.html; "China is Opening a New Quantum Research Supercenter," *Popular Science,* 20 October 2017, https://www.popsci.com/chinas-launches-new-quantum-research-supercenter; "China aims to become world leader in AI, challenges U.S. dominance," *Reuters,* 20 July 2017, https://www.reuters.com/article/us-china-ai/china-aims-to-become-world-leader-in-ai-challenges-u-s-dominance-idUSKBN1A5103

[77] For a review of Chinese protectionism, see, for example, *Chapter 1: U.S.-China Economic and Trade Relations* p. 35-140 of "2017 Annual Report," US-China Economic and Security Commission, 15 November 2017, or "American Business in China," AmCham China, 2017.

[78] According to the "Findings of the Investigation Into China's Acts, Policies, and Practices Related to Technology Transfer, Intellectual Property, and Innovation Under Section 301 of the Trade Act of 1974," Office of the U.S. Trade Representative, 03/22/18, p. 6, https://ustr.gov/sites/default/files/Section%20301%20FINAL.PDF*:* "Technology is defined broadly in this investigation to include knowledge and information needed to produce and deliver goods and services, as well as other methods and processes used to solve practical, technical or scientific problems. In addition to information protected by patents, copyrights, trademarks, trade secrets, and other types of

intellectual property protections, the term also includes "know-how," such as production processes, management techniques, expertise, and the knowledge of personnel."

[79] Forced technology transfer is prohibited by the World Trade Organization rules.

[80] Documentation of China's domination of global manufacturing dates back to Peter Navarro and Greg Autry, *Death By China*, Pearson FT Press, May 2011.

[81] As evidence of China's use of overcapacity in the solar and steel industries, see, for example, "Press Release: China's Industrial Overcapacity is Destroying Key European Industries," AEGIS Europe, 14 July 2016. For autos, see, for example, Trivedi, Anjani, "China Looks to Export Auto Overcapacity on Slow-Growth World," *The Wall Street Journal*, 1 May 2017. For robotics, see, for example, Bland, Ben, "China's Robot Revolution Poses US Risks, Warns Wilbur Ross," *Financial Times*, 27 September 2017.

[82] Department of Justice, Office of Public Affairs, "US Charges Five Chinese Military Hackers for Cyber Espionage Against US Corporations and a Labor Organization for Commercial Advantage," 19 May 2014.

[83] Department of Justice, "United States of America v. Wang Dong, Sun Kailiang, Wen Xinyu, Huang Zhenyu, Gu Chunhui," 1 May 2014, pg 14-15.

[84] Coalition for American Solar Manufacturing, "Analysis: China's New Five-Year Plan for Solar Calls for Escalation in Government Sponsorship of Export-Intensive, Price-Subsidized Trade," 2 May 2012. http://www.americansolarmanufacturing.org/news-releases/05-02-12-chinas-five-year-plan.htm

[85] Department of Commerce, International Trade Administration, "Fact Sheet: Commerce Finds Dumping and Subsidization of Crystalline Silicon Photovoltaic Cells, Whether or Not Assembled into Modules from the People's Republic of China," 2012. http://ia.ita.doc.gov/download/factsheets/factsheet_prc-solar-cells-ad-cvd-finals-20121010.pdf

[86] As reported by the "Findings of the Investigation Into China's Acts, Policies, and Practices Related to Technology Transfer, Intellectual Property, and Innovation Under Section 301 of the Trade Act of 1974," Office of the U.S. Trade Representative, 03/22/18, p. 158-159, https://ustr.gov/sites/default/files/Section%20301%20FINAL.PDF: "In 2012, while SolarWorld was litigating a petition it had filed against solar imports from China, the 3PLA stole thousands of sensitive files from SolarWorld. According to the indictment, these files included: "(i) cash-flow spreadsheets that would enable a competitor to identify how long SolarWorld would be able to withstand a market shock; (ii) detailed manufacturing metrics, technological innovations, and production line information that would enable a competitor to imitate SolarWorld's proprietary production capabilities; (iii) production costs for manufacturing inputs that would enable a competitor to undermine SolarWorld financially through underpricing of solar products; and, (iv) privileged attorney-client communications regarding SolarWorld's ongoing trade litigation with China, including confidential Question and Answer documents submitted to the [Department of Commerce] that were not discoverable by the Chinese respondents. According to the indictment, "such information would have enabled a Chinese competitor to target SolarWorld's business operations aggressively from a variety of angles."

[87] European Chamber of Commerce, "China Manufacturing 2025," 2017, pg 2. http://www.europeanchamber.com.cn/en/china-manufacturing-2025

[88] Arne Delfs and Patrick Donahue, "German Spy Chief Says China's Tech Takeovers Are a Security Risk," *Bloomberg*, 24 June 2018.

[89] The Associated Press, "Australia Bans Huawei From 5G Network Over Security Concerns," *The New York Times*, 23 August 2018.

[90] This strategy has already been highly successful. China controls over 95% of the world's rare earth minerals; see "Rare earths: Battling China's monopoly after Molycorp's demise," *Mining.com,* 10 September 2016. http://www.mining.com/rare-earths-battling-chinas-monopoly-after-molycorps-debacle/

[91] China's highly successful neo-colonial approach to securing global resources is documented in Peter Navarro and Greg Autry, *Death By China*, Pearson FT Press, May 2011, Chapter 7. See also "2017 Annual Report," US-China Economic and Security Commission, 15 November 2017.

[92] United States Census Bureau, "Trade in Goods with China," 1985-2017. https://www.census.gov/foreign-trade/balance/c5700.html

[93] Demand for U.S. dollars to buy U.S. Treasuries drives up the value of the U.S. dollar relative to the yuan. For discussion, see, for example, Global Finance School, "How China Keeps the Yuan Undervalued," Undated. https://www.globalfinanceschool.com/blog-post/how-china-keeps-yuan-undervalued As this missive notes: "How does China keep the Yuan weak? By buying US currency and treasury notes on the open market, China keeps demand for the US dollar high. They can afford to buy and hold so much US currency due to their huge trade surplus with America, and they buy US currency roughly equal to this surplus. To keep the influx of dollars from increasing the Chinese money supply, China "sterilizes" the dollar purchases by selling bonds to Chinese investors like commercial banks. By boosting the dollar, still one of the most powerful worldwide currencies, the Yuan looks weak in relation."

[94] For a discussion generally of how foreign governments help finance U.S. trade deficits, see John Benedetto, "Who Financed Recent Trade Deficits?" United States International Trade Commission, *Journal of International Commerce and Economics,* May 2014. https://www.usitc.gov/publications/332/journals/volume_vi_u_s_trade_deficit.pdf

[95] World Bank Open Data, multiple data pulls, https://data.worldbank.org/.

[96] Christine Kim and Ben Blanchard, "China, South Korea Agree to Mend Ties After THAAD Standoff," *Reuters*, 30 October, 2017.

[97] Andrew Higgins, "In Philippines, Banana Growers Feel Effect of South China Sea Dispute," *Washington Post,* 10 June 2012.

[98] *The Japan Times*, "No Improvement in China's Rare Earths Ban," 13 October 2010.

[99] Ralph Jennings, "China's Efforts to Increase Pressure on Old Foe Taiwan Are Backfiring," *Forbes*, 28 June 2017.

[100] Kai Schultz, "Sri Lanka, Struggling With Debt, Hands a Major Port to China," *The New York Times,* 12 December 2017.

[101] Chamber of Commerce of the United States of America, "China's Drive for 'Indigenous Innovation' A Web of Industrial Policies," 2010. https://www.uschamber.com/sites/default/files/documents/files/100728chinareport_0_0.pdf

[102] Center for Strategic and International Studies, "Made in China 2025," 1 June 2025. https://www.csis.org/analysis/made-china-2025

[103] *Ibid.*

[104] Office of the U.S. Trade Representative, "Findings of the Investigation into China's Acts, Policies, and Practices Related to Technology Transfer, Intellectual Property, and Innovation Under Section 301 of the Trade Act of 1974," 22 March 2018. https://ustr.gov/sites/default/files/Section%20301%20FINAL.PDF

[105] China's illegal activities include cyberattacks, cyber theft, and industrial espionage. State-backed hackers steal, on average, $300 billion of intellectual property per year. While cyber theft has garnered most public attention, the FBI has cited a rise in industrial espionage: caseloads grew 53% from 2013-2015, with 95% of cases believed to be perpetrated by China. One source estimates that China employed 250,000-300,000 cyber spies in 2010 and 30,000 to 50,000 humans engaged in insider industrial espionage. Source: Intellectual Property Commission, "2017 Update to the IP Commission Report," February 2017. http://www.ipcommission.org/ The 2013 Intellectual Property Commission Report estimated that 96% of global cyber espionage originated in China and has led to $100 billion in lost sales and 2.1 million lost jobs. Together, these strategies will give China access to the world's most advanced capabilities and will erode our technological dominance over time.

[106] China uses five major means to acquire the IP and technologies of America. These include: (1) industrial espionage and sabotage through traditional spycraft, cyber espionage, and reverse engineering, counterfeiting, and piracy; (2) evasion of U.S. restrictions on technology transfers; (3) coercive regulatory gambits to force technology transfers from U.S. companies, typically in exchange for limited access to the Chinese market; (4) state-sponsored strategic Chinese investment in the U.S. through vehicles such as

acquisitions, greenfield investment, and venture capital financing, often involving elaborate front companies and shell corporations and opaque investor networks; and (5) the harvesting of America's national security innovation base through a massive open source collection campaign; the presence of large cadres of state-directed Chinese nationals at America's universities, national labs, and other centers of innovation; and a highly coordinated and government-financed program of talent recruitment aimed at business, finance, science, and technology experts. As is apparent, some of these techniques are illegal either at the national or multilateral (WTO) level, and some are not. For discussion, see the Office of Trade and Manufacturing Policy's report on Chinese economic aggression, January 2018.

[107] Rhodium Group, "Two-Way Street: 2017 Update US-China Direct Investment Trends," May 2017.

[108] Michael Brown and Pavneet Singh, "China's Technology Transfer Strategy: How Chinese Investments in Emerging Technology Enable A Strategic Competitor to Access the Crown Jewels of U.S. Innovation ," Defense Innovation Unit Experimental, January 2018, p. 4, https://admin.govexec.com/media/diux_chinatechnologytransferstudy_jan_2018_(1).pdf.

[109] *Ibid.*

[110] In addition to sensitive reporting, the U.S. Department of Defense has discussed these issues in its various reports to Congress on China's military developments. The most recent report is available at: https://www.defense.gov/Portals/1/Documents/pubs/2017_China_Military_Power_Report.PDF

[111] For a discussion of the U.S.-China military balance in the open source, see the most recent U.S. Department of Defense report to Congress on China's military developments, It is available at: https://www.defense.gov/Portals/1/Documents/pubs/2017_China_Military_Power_Report.PDF

[112] Department of Defense, "Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2017," 15 May 2017. https://www.defense.gov/Portals/1/Documents/pubs/2017_China_Military_Power_Report.PDF

[113] Department of Defense, "Report to Congress: Annual Industrial Capabilities." 16 March 2017. http://www.businessdefense.gov/Portals/51/Documents/Resources/2016%20AIC%20RTC%2006-27-17%20-%20Public%20Release.pdf?ver=2017-06-30-144825-160

[114] *Ibid.*

[115] Daniel Kliman, Testimony before the U.S.-China Economic and Security Review Commission, 25 January 2018. https://www.uscc.gov/sites/default/files/Kliman_USCC%20Testimony_20180119.pdf

[116] U.S.-China Economic and Security Review Commission, "China's High-Speed Rail, Diplomacy, 21 February 2017. https://www.uscc.gov/sites/default/files/Research/China%27s%20High%20Speed%20Rail%20Diplomacy.pdf

[117] Adam Davidson, "Most U.S. Port Terminals Are Foreign-Run," National Public Radio, 26 February 2006. https://www.npr.org/templates/story/story.php?storyId=5234177

[118] For a recognition of the threat in the telecommunications sector by the U.S. Congress, see Wolf, Jim. "U.S. Lawmakers Seek to Block China Huawei, ZTE U.S. Inroads," Reuters, 7 October 2012.

[119] Data provided by Institute for Defense Analyses.

[120] Manufacturing Institute and Deloitte, "The Skills Gap in U.S. Manufacturing: 2015 and Beyond," 2015, pg. 7. http://www.themanufacturinginstitute.org/~/media/827DBC76533942679A15EF7067A704CD/2015_Skills_Gap_Report.pdf

[121] *Ibid*, pg 15.

[122] *Ibid*, pg 13.

[123] National Science Foundation, Science and Engineering Indicators, 2018. https://www.nsf.gov/statistics/2018/nsb20181/digest/sections/u-s-and-global-stem-education

[124] National Science Foundation, Science and Engineering Indicators, 2014. https://www.nsf.gov/statistics/seind14/index.cfm/chapter-2/c2s2.htm#s2-2

[125] *Ibid.*

[126] *Ibid.*

[127] Matthew Patane, "Creston helicopter parts maker Fansteel files for bankruptcy," *Des Moines Register,* September 2016. https://www.desmoinesregister.com/story/money/business/2016/09/15/creston-helicopter-parts-maker-fansteel-files-bankruptcy/90407356/

[128] National Association of Manufacturers, Manufacturers Outlook Survey, December 2017. http://www.nam.org/Data-and-Reports/Manufacturers-Outlook-Survey/2017-Fourth-Quarter-Manufacturers-Outlook-Survey/

[129] Ben Watson, "The US Army Just Ordered Soldiers to Stop Using Drones from China's DJI," *Defense One*, 4 August 2017.

[130] Internet Security Threat Report, Symantec, 2015.

[131] Data Breach Investigations Report, Verizon, 2015.

[132] Manufacturers received 20% of all attacks across all industries globally in 2014. Symantec. "Internet Security Threat Report," 2015, pg 13.

[133] Cyber-espionage consisted of 60% of all attacks on manufacturers in 2014. In fact, manufacturers received more cyber-espionage attacks than any other industry globally in 2014 (27.4%, p. 52). Other motivations for attacks on manufacturers were crimeware (malicious software designed to carry out or facilitate illegal online activity, 34%), insider misuse (4%) and web-app attacks (1%) (p. 34). Verizon, "Data Breach Investigations Report," 2015.

[134] Studies by organizations such as the National Defense Industry Association, Defense Science Board, Alliance for Manufacturing Foresight, and McKinsey Global Institute have also highlighted (1) the centrality of small and medium manufacturers to the U.S. manufacturing supply chain for domestic economic growth, (2) small and medium manufacturers criticality to the DIB for national security, and (3) small and medium manufacturers vulnerability to cybersecurity threats and breaches.

[135] While multiple size standards exist for different industry sectors, the U.S. Small Business Administration generally considers small and medium-sized manufacturers to have fewer than 500 employees at a location.

[136] NDIA, "Cybersecurity for Manufacturing Networks," 2017.

[137] IC Insights, "2018 Integrated Circuit Market Drivers," 2017.

[138] Semiconductor Industry Association, "2017 Factbook," May 2017.

[139] DIBNow data extraction, NAICS code 304, 24 January 2018.

[140] World Electronic Circuits Council (WECC), "WECC Global PCB Production Report for 2015," *WECC*, October 2016.

[141] Ibid.

[142] Semiconductor Industry Association, "2017 Factbook," May 2017.

[143] A "foundry" is a semiconductor manufacturing facility that manufactures third party designs.

[144] Interview with Brian Papke, President of Mazak USA, 16 November 2017.

[145] Dashan Kalyani, "IBISWorld Industry Report 33351 Metalworking Machinery Manufacturing in the U.S.," September 2017, IBISWorld Inc.

[146] Steven Kline, Jr. "Understanding the Machine Tool Industry's Ups and Downs," *Modern Machine Shop Online*, https://www.mmsonline.com/articles/understanding-the-machine-tool-industrys-ups-and-downs, 1 May 2017.

[147] Gardner Research World Machine Tool Survey, 2016, p6. https://www.gardnerweb.com/articles/2016-world-machine-tool-survey

[148] Dashan Kalyani, "IBISWorld Industry Report 33351 Metalworking Machinery Manufacturing in the U.S.," September 2017, IBISWorld Inc.

[149] Department of Defense, "Report to Congress: Annual Industrial Capabilities," 16 March 2017. http://www.businessdefense.gov/Portals/51/Documents/Resources/2016%20AIC%20RTC%2006-27-17%20-%20Public%20Release.pdf?ver=2017-06-30-144825-160

[150] Department of Interior, U.S. Geological Survey, Mineral Commodity Summaries, 2018. https://minerals.usgs.gov/minerals/pubs/mcs/2018/mcs2018.pdf

[151] National Academy of Sciences, Managing Materials for a Twenty-first Century Military, DOI 10.17226/12028. 2008. http://nap.edu/12028

[152] Zina D. Merrit, et al., Defense Supply Chain: DOD Needs Complete Information on Single Sources of Supply to Proactively Manage the Risks. GAO-17-768, Government Accountability Office, Washington, 2017. https://www.gao.gov/assets/690/687432.pdf

[153] Congressional Research Service, Rare Earth Elements in National Defense: Background, Oversight Issues, and Options for Congress, CRS Report No. R41744, 2013. http://www.dtic.mil/dtic/tr/fulltext/u2/a590410.pdf

[154] Congressional Research Service, The Buy American Act—Preferences for "Domestic" Supplies: In Brief, CRS Report No. R43140, 2016. https://www.hsdl.org/?abstract&did=792493

[155] Congressional Research Service, The Specialty Metal Clause: Oversight Issues and Options for Congress, CRS Report No. RL33751, 2014. https://www.everycrsreport.com/files/20140206_RL33751_a9432dab10baa886b9c902c56d2aec279d29b844.pdf

[156] Congressional Research Service, China's Mineral Industry and U.S. Access to Strategic and Critical Minerals: Issues for Congress, CRS Report No. R43864 2015. https://fas.org/sgp/crs/row/R43864.pdf

[157] Naval Registry.

[158] Vehicle, missiles, and aircraft numbers derived from Service Property Book data repositories.

[159] Log Cost Baseline calculation.

[160] Maintenance and Availability Data Warehouse.

[161] Bureau of Labor Statistics.

[162] Federal Reserve Bank of St. Louis, FRED. https://fred.stlouisfed.org/series/MANEMP. Not all manufacturing job loss represents diminished U.S. manufacturing; some has been caused by automation within manufacturing facilities that have remained in the United States.

[163] National Association of Manufacturers, Manufacturers Outlook Survey, December 2017. http://www.nam.org/Data-and-Reports/Manufacturers-Outlook-Survey/2017-Fourth-Quarter-Manufacturers-Outlook-Survey/

[164] National Association of Manufacturers, *Economic Report*, March 2018. http://www.nam.org/Newsroom/eNewsletters/Monday-Economic-Report/2018/Monday-Economic-Report---March-19--2018/

[165] National Science Foundation, Science and Engineering Indicators, 2018. https://www.nsf.gov/statistics/2018/nsb20181/digest/sections/u-s-and-global-stem-education

[166] National Science Foundation, Science and Engineering Indicators, 2014. https://www.nsf.gov/statistics/seind14/index.cfm/chapter-2/c2s2.htm#s2-2

[167] *Ibid.*

[168] *Ibid.*

[169] U.S. Department of Commerce, Bureau of Industry and Security, "Critical Facilities Assessment – Preliminary," 2017.

[170] Bureau of Labor Statistics.

[171] For more information, please: http://www.businessdefense.gov/security-of-supply/.

[172] See Defense Federal Acquisition Regulations 225.872-1: Other International Agreements and Coordination.

[173] For more information, see:
https://www.acq.osd.mil/dpap/cpic/ic/reciprocal_procurement_memoranda_of_understanding.html

This page intentionally blank.

Office of the Under Secretary of Defense
for Acquisition and Sustainment

Office of the Deputy Assistant Secretary of Defense
for Industrial Policy