

ANNUAL REPORT TO CONGRESS

FISCAL YEAR 2018

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INDUSTRIAL CAPABILITIES

Office of the Under Secretary of Defense
for Acquisition and Sustainment

Office of the Deputy Assistant Secretary of Defense
for Industrial Policy



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REQUIREMENT

This report is being provided to the Committee on Armed Services of the Senate and the Committee on Armed Services of the House of Representatives. This report simultaneously satisfies the requirements pursuant to title 10 United States Code (U.S.C.), section 2504, which requires the Department of Defense (DoD) to submit an annual report summarizing DoD industrial capabilities-related guidance, assessments, and actions and Senate Report 112-26, which accompanies section 1253, the NDAA for FY 2012, and requires a report containing a prioritized list of investments to be funded in the future under the authorities of Title III of the Defense Production Act (DPA) of 1950. This report summarizes DoD industrial capabilities-related guidance, assessments, and actions initiated during FY 2018 and as they existed at the close of that fiscal year.

Starting this year, the annual industrial capabilities report will also provide Congress with updates related to the implementation and execution of the industrial base risk mitigation strategies and follow-on efforts related to Executive Order 13806 on Assessing and Strengthening the Manufacturing and Defense Industrial Base and Supply Chain Resiliency of the United States. The updates include assessments and actions executed between FY 2018 and March of FY 2019.

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TABLE OF CONTENTS

1. Office of Industrial Policy Introduction	1
1.1. Mission	1
1.2. Organization Structure	1
2. National Defense Strategy	5
2.1. Build a More Lethal Force.....	5
2.2. Strengthen Alliances and Attract New Partners	7
2.3. Reform the Department of Defense for Greater Performance and Affordability .	10
2.3.1. Changes to DoD Organizational Structure.....	10
2.3.2. Business Reforms to Improve Performance and Increase Affordability	11
3. Defense Industry Outlook.....	17
3.1. The Defense Industrial Base is Profitable and Expanding	17
3.2. Supplier Assessment	18
3.3. Changes in DoD Obligations and Vendor Composition	20
3.4. Outlook and Challenges	22
4. U.S. Position in the Global Defense Markets	25
4.1. United States Contribution to Global Defense Spending.....	25
4.2. Defense Exports and Foreign Military Sales	26
4.3. Competitor Nations	27
5. Executive Order 13806—Assessing and Strengthening the Manufacturing and Defense Industrial Base and Supply Chain Resiliency of the United States	29
5.1. Aircraft	33
5.1.1. Sector Overview.....	33
5.1.2. Sector Risks and Mitigation Strategy.....	33
5.2. Chemical, Biological, Radiological, and Nuclear	36

5.2.1.	Sector Overview	36
5.2.2.	Sector Risks and Mitigation Strategy	36
5.3.	Ground Systems	38
5.3.1.	Sector Overview	38
5.3.2.	Sector Risks and Mitigation Strategy	38
5.4.	Munitions and Missiles	41
5.4.1.	Sector Overview	41
5.4.2.	Sector Risks and Mitigation Strategy	42
5.5.	Nuclear Matter Warheads	45
5.5.1.	Sector Overview	45
5.5.2.	Sector Risks and Mitigation Strategy	45
5.6.	Radar and Electronic Warfare	47
5.6.1.	Sector Overview	47
5.6.2.	Sector Risks and Mitigation Strategy	48
5.7.	Shipbuilding	51
5.7.1.	Sector Overview	51
5.7.2.	Sector Risks and Mitigation Strategy	52
5.8.	Soldier Systems	56
5.8.1.	Sector Overview	56
5.8.2.	Sector Risks and Mitigation Strategy	57
5.9.	Space	59
5.9.1.	Sector Overview	59
5.9.2.	Sector Risks and Mitigation Strategy	61
5.10.	Materials	66
5.10.1.	Sector Overview	66
5.10.2.	Sector Risks and Mitigation Strategy	67
5.11.	Cybersecurity for Manufacturing	70
5.11.1.	Sector Overview	70
5.11.2.	Sector Risks and Mitigation Strategy	70
5.12.	Electronics	74
5.12.1.	Sector Overview	74

5.12.2. Sector Risks and Mitigation Strategy.....	74
5.13. Machine Tools.....	77
5.13.1. Sector Overview.....	77
5.13.2. Sector Risks and Mitigation Strategy.....	77
5.14. Organic Defense Industrial Base	80
5.14.1. Sector Overview.....	80
5.14.2. Sector Risks and Mitigation Strategy.....	81
5.15. Software Engineering	85
5.15.1. Sector Overview.....	85
5.15.2. Sector Risks and Mitigation Strategy.....	85
5.16. Workforce.....	90
5.16.1. Sector Overview.....	90
5.16.2. Sector Risks and Mitigation Strategy.....	90
5.17. Executive Order 13806 Action Plan and Next Steps	99
6. Critical New Technologies	101
6.1. Industrial Base Assessment of Critical New Technologies	101
6.2. Assessments and Technologies	101
6.2.1. Hypersonics.....	101
6.2.2. Directed-Energy Weapons.....	102
6.2.3. Artificial Intelligence (AI)/Machine Learning	102
6.2.4. Quantum Science.....	102
6.2.5. Microelectronics	102
6.2.6. Fully Networked Command Control and Communications	103
6.2.7. Space.....	103
6.2.8. Autonomy	103
6.2.9. Cyber	103
7. Conclusion.....	105
Appendix A: Annual Report Requirements	108
Appendix B: DoD Authorities to Support the Industrial Base	109

Appendix C: Key Industrial Capabilities Assessments Completed During
FY 2018..... 110

Appendix D: Title III, IBAS, and ManTech Projects 111

Appendix E: List of Acronyms..... 112

Appendix F: Photo Credits 115

Appendix G: References 117

TABLE OF FIGURES

Figure 1. Industrial Policy Organization Structure.....	2
Figure 2. Stock Performance Trend by Market Sector [CY 2012–CY 2018] (2012 baseline) .	17
Figure 3A. EBITDA Margin (%) of the Largest Six DoD Primes [CY 2012–CY 2017]	18
Figure 3B. EBITDA Margin (%) of DoD Contractors [CY 2012–CY 2017].....	18
Figure 4. Big Six Defense Contractors—Revenue Breakdown [CY 2012–CY 2017].....	19
Figure 5. Obligation by Product and Service [FY 2012–FY 2018]	20
Figure 6. Aircraft, Ships/Submarines, and Land Vehicles [FY 2012–FY 2018].....	20
Figure 7. DoD RDT&E Budget vs. Big 6 R&D Spend (Sales Weighted Avg.).....	21
Figure 8. DoD Budget Authority—RDT&E, Procurement, O&M [FY 2007–FY 2023]	22
Figure 9. DoD Budget Authority—O&M [FY 2007–FY 2023]	22
Figure 10. DoD Budget Authority—Procurement [FY 2007–FY 2023].....	23
Figure 11. DoD Budget Authority—RDT&E [FY 2007–FY 2023].....	23
Figure 12. Global Military Spending [CY 2007–CY 2017]	25
Figure 13. Top 23 Defense Companies per Arms Sales (CY 2016) Billions USD.....	27
Figure 14. 2017 Top Russian Arms Importers	28
Figure 15. List of Traditional and Cross-Cutting Sectors	30
Figure 16. Manufacturing and Defense Industrial Base Risk Framework.....	30
Figure 17. Space Sector Taxonomy: Launch Services	60
Figure 18. Space Sector Taxonomy: Satellites and Sensors	60
Figure 19. General rare earth element processing steps required to make a NdFeB magnet.	67
Figure 20. Bachelor’s Degree Awards in S&E Fields, by selected region, country, or economy: 2000–2014.....	87

TABLE OF TABLES

Table 1. Definitions of the Five Macro Forces Driving Risks into America’s Industrial Base ..	31
Table 2. Ten Risk Archetypes Threatening America’s Manufacturing and Defense Industrial Base	31
Table 3. Shipyards Engaged in U.S. Naval Construction.....	51



1. Office of Industrial Policy Introduction

1.1. Mission

The mission of the Office of Industrial Policy (INDPOL) in the Office of the Secretary of Defense is to ensure robust, secure, resilient, and innovative industrial capabilities upon which the Department of Defense (DoD) can rely to fulfill current and future warfighter requirements in an era of great power competition.

The 2018 National Defense Strategy (NDS) emphasized the importance of the Defense Industrial Base (DIB) in achieving a more lethal, resilient, and rapidly innovating Joint Force. The national security of the United States requires the technological and intellectual capabilities of domestic and foreign companies, academia, and dual-use technology providers collaborating at the forefront of future generation technologies, along with the sub-tiers and components suppliers that support them.

As part of its mission, INDPOL brings this diverse set of players together to form an ecosystem that is committed to the health and vitality of the industrial base and the domestic economy as a whole. The Office plays a critical role in representing DoD interests on interagency committees regarding business and economic issues relevant to national security.

1.2. Organization Structure

The Office of Industrial Policy is divided into seven groups. These seven groups, included in Figure 1, work together to sustain a healthy industrial base and support NDS priorities.

- **Policy and Outreach:** The Policy and Outreach group leads the strategic efforts for industrial base challenges for the Under Secretary of Defense for Acquisition and Sustainment (USD(A&S)). As lead for the response to Executive

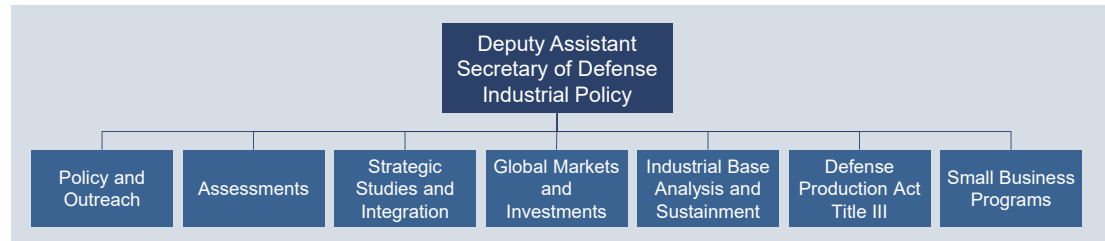


Figure 1. Industrial Policy Organization Structure

Order (EO) 13806, Assessing and Strengthening the Manufacturing and Defense Industrial Base and Supply Chain Resiliency of the United States, the group implements the action plan and risk mitigations, including creation of an industrial policy framework for DoD. Outreach encompasses all activities between the USD(A&S) and domestic and international industry partners. Through increased collaboration and communication with industry partners, the outreach activities support the goal of a healthy, robust, and secure industrial base to meet warfighter requirements. Outreach activities also include government-to-government dialogue with allies and partners on joint industrial base concerns and areas of potential collaboration.

- **Assessments:** The Assessments group integrates subject matter expertise, market analysis, and the principles of big data to identify industrial base risks and issues and establish mitigation strategies. This group covers three main areas:
 - **Assessments**—Subject matter experts work with DoD and interagency partners to identify, mitigate, and monitor risks and issues across the industrial base as part of the assessment activities. The group’s data-driven analyses and technical assessments include, but are not limited to, industrial sector summaries, fragility and criticality assessments, capacity analysis, and budgetary impacts on the industrial base. These assessments provide strategic views of the industrial base and help inform the Department to implement budgetary, programmatic, and legislative policies to ensure a strong and resilient industrial base. This team’s portfolio also includes management of the Defense Priorities and Allocations System (DPAS), Defense Production Act (DPA) Title I. Title I provides the President the authority to require performance on contracts and orders to meet national defense and emergency preparedness program requirements. Under this authority, DoD requests special priority assistance to resolve conflicts among critical contracts and orders.

- **Mergers & Acquisitions (M&A)**—The Hart–Scott–Rodino Act (HSR)* established the federal premerger notification program, which provides the Federal Trade Commission (FTC) and the Department of Justice with information about large mergers and acquisitions before they occur. These antitrust agencies work with DoD to ensure that mergers and acquisitions do not reduce competition or cause market distortions that are not in the Department’s ultimate best interest. From all the M&A transactions filed with the antitrust agencies, the Department reviews only the transactions with a potential impact to DoD interest. The Mergers & Acquisition team leads DoD’s HSR acquisition review activity to determine which acquisitions are likely to be anticompetitive and/or have a negative impact to national security, and to challenge the parties involved at a time when remedial action is most effective.

- **Business Intelligence and Analytics (BI&A)**—INDPOL’s BI&A program supports proactive industrial base assessments through the development of data applications and data-driven analysis. Taking advantage of big data principles, the BI&A program uses government, commercial, and open data sources to facilitate analysis of defense suppliers, sectors, and transactions and enhance visibility into defense supply chains. In FY 2018, INDPOL’s business intelligence platform, “DIBNow,” received authorization to operate, and launched to a community of test users across DoD. The platform securely integrates diverse data sets to provide users with impactful analytics covering a range of industrial base issues and risks. Future development efforts will focus on increasing the scope of risk scoring within the platform and enhancing data on suppliers within the supply chain.

- **Strategic Studies and Integration:** This Strategic Studies and Integration group was formed in fiscal year 2019. The group reviews and reports on critical technologies, develops programs to increase participation of small and medium companies in the manufacturing industrial base, and supports the development of integrated strategies across INDPOL and other offices in DoD.

- **Global Markets and Investments (GMI):** The GMI group manages the Committee on Foreign Investment in the United States (CFIUS) process for DoD. This group works with more than 30 stakeholders within DoD, as well as other government agencies, to review certain transactions involving foreign investment in the United States in order to assess the impact of such transactions on the national security of the United States. The group has a robust non-notified team that leverages diverse analytical tools to identify transactions that were not voluntarily notified to CFIUS. They conduct intense analysis of both notified and non-notified transactions for national security risks. If risks are identified, the GMI group prepares risk-based analysis and

* Hart–Scott–Rodino Antitrust Improvements Act of 1976 (Public Law 94-435)

either drafts mitigation agreements or prepares the case for transmittal to the President of the United States with a recommendation for prohibition. If a case is mitigated, a dedicated team monitors the agreements for compliance, including conducting on-site inspections and meetings. Being recognized as the international leader in foreign direct investment (FDI) matters, GMI engages in collaborative discussions with international partners to help develop FDI capabilities in allied nations.

- **Industrial Base Analysis and Sustainment (IBAS):** The IBAS group enables investments to close gaps in defense manufacturing capabilities and creates and sustains reliable sources of supply that are critical to DoD's focus on readiness and lethality. The group concentrates on advancing and sustaining traditional defense manufacturing sectors, proactively mitigates supply chain vulnerabilities within the global DIB, plans for the next generation and emerging manufacturing and technology sectors, and leverages global manufacturing innovation through the development of partnerships.
- **Defense Production Act (DPA) Title III:** The DPA Title III program manages the Department's expansion of productive capacity and supply responsibilities under the 1950 Defense Production Act. Title III of the DPA provides the President broad authority to ensure timely availability of domestic industrial resources essential for the execution of the national security strategy of the United States through the use of tailored economic incentives. Title III authorities are designed to develop, maintain, modernize, restore, and expand the productive capacities of domestic sources for critical components, critical technology items, materials, and industrial resources, to support national defense and homeland security requirements. The authorities may be employed when the President determines that domestic industrial capabilities essential to national defense do not exist, are at risk of being lost, or are insufficient to meet essential government needs. Title III actions stimulate private investment in industrial resources by reducing the risks associated with the capitalization and investments required to establish the needed production capacity.
- **Office of Small Business Programs (OSBP):** The OSBP group advises the Secretary of Defense on all small business matters and is responsible for maximizing opportunities for small businesses to contribute combat power for our troops and economic power for our nation. This group helps maximize opportunities to ensure that the nation's small businesses remain responsive, resilient, secure, and diversified. Group-managed initiatives, like the pilot Mentor-Protégé Program (MPP), provide incentives for DoD contractors to support small businesses through enhanced capabilities and opportunities to increase their participation in government contracts.



2. National Defense Strategy

In FY 2018, DoD published the latest version of the National Defense Strategy (NDS). The NDS provides the U.S. strategy to compete, deter, and win in a complex security environment that is defined by rapid technological changes, new threats, and the impact of an extended armed conflict on readiness. The FY 2018 NDS directs:

“New commercial technology will change society and, ultimately, the character of war. The fact that many technological developments will come from the commercial sector means that state competitors and non-state actors will also have access to them, a fact that risks eroding the conventional overmatch to which our Nation has grown accustomed. Maintaining the Department’s technological advantage will require changes to industry culture, investment sources, and protection across the National Security Innovation Base.”

In order to generate decisive and sustained U.S. strategic and tactical advantages, DoD focuses its efforts on rebuilding military readiness to train and develop a more lethal Joint Force, strengthening alliances as we attract new partners, and reforming DoD’s business practices for greater performance and affordability.

The following outlines initiatives and activities led by INDPOL during FY 2018 in support of each of the NDS lines of effort.

2.1. Build a More Lethal Force

As directed in the NDS, the nation must field sufficient and capable forces to defeat enemies and achieve sustainable outcomes that protect the American people and its interests. The Department of Defense recognizes that the United States cannot

expect success fighting tomorrow's conflicts with yesterday's thinking, weapons, or equipment.* The contributions of INDPOL toward building a more lethal Joint Force included the following:

- Led interagency efforts for EO 13806, Assessing and Strengthening the Manufacturing and Defense Industrial Base and Supply Chain Resiliency of the United States. Results of the EO 13806 assessment are provided in Section 5 of this report.
- Managed the allocation of industrial resources to mitigate a critical shortage of semiconductor wafers used in voltage control switches for critical (high use) DoD missile systems. This work ensured that critical munitions' requirements were met, by balancing the Services' requirements and priorities to industry's production capacity.
- Supported the Deputy Secretary's "Munitions War Room" efforts to ensure DoD readiness via current munitions inventory levels. The Department conducted a capacity analysis to identify critical munitions that have inventory shortfalls and/or are being depleted by current operations. Industry and DoD collaborated to identify and mitigate key bottlenecks that limited industry's ability to ramp up production of these critical munitions.
- The DPA Title III program's portfolio of 32 projects at the end of CY 2018 bolsters critical sectors of the industrial base to increase the lethality and readiness of the nation.† In FY 2018, and in support of EO 13806, the President signed Presidential Determinations authorizing the use of DPA Title III authorities to address key industrial base shortfalls in the production of metal castings for critical rotorcraft applications and trusted advanced photomasks for microelectronics. Additionally, the DPA Title III program developed numerous recommendations for the President regarding a broad set of industrial base challenges identified in the EO 13806 report for which utilizing DPA Title III authorities may be required. Through March 2019, seven Presidential Shortfall Determinations have been issued addressing key industrial base shortfalls in lithium sea-water batteries, alane fuel cell technology, sonobuoys production, and critical chemicals production for missiles and munitions. Work is ongoing to address additional areas highlighted in the EO 13806 report, such as key shortfalls in the rare earths supply chain.
- The IBAS group supported the health and resiliency of the supply chain by investing in projects related to manufacturing skills, radar, directed energy, and solid rocket motors.‡

* Paraphrased from the Secretary of Defense's written statement for the House Armed Services Committee, 4/12/2018.

† See Appendix D for detailed information about DPA Title III projects.

‡ See Appendix D for detailed information about IBAS projects.

- The Assessments group led 15 M&A reviews with potential impact to DoD. This group also worked closely with partners in the Department of Commerce (DOC) to provide input on the effect of global trade on critical areas such as steel, aluminum, and other commodities and their importance to DoD.
- The OSBP group played a critical role in contributing to the lethality of our warfighters through engagement with small businesses. The Department awarded 23.86% of small business eligible contracts to qualified small businesses in FY 2018. The DoD MPP, which pairs small businesses with larger businesses, impacted major defense programs including the Standard Missile-3 (SM-3), the F-35 aircraft, the KC-130J aircraft, the AN/APY-10 maritime/overland radar, the AN/FPS-132 upgraded early warning radar, and the P-8A Poseidon.
- The GMI group contributed to the creation of the Foreign Investment Risk Review Modernization Act (FIRRMA) legislation. It was passed into law as part of the FY 2019 National Defense Authorization Act (NDAA). This legislation expands CFIUS's authority to review foreign investment into defense critical technologies and defines factors affecting national security, including the effect of foreign investment on U.S. technological leadership, critical infrastructure, and the capability of domestic industries to meet national defense requirements. The GMI group reviewed 235 CFIUS cases in FY 2018 and, with the passage of FIRRMA, expects significantly more cases in 2019.

2.2. Strengthen Alliances and Attract New Partners

The NDS highlights the need to strengthen traditional alliances while also building new partnerships. The FY 2018 NDS states:

“By working together with allies and partners we amass the greatest possible strength for the long-term advancement of our interests, maintaining favorable balances of power that deter aggression and support the stability that generates economic growth. When we pool resources and share responsibility for our common defense, our security burden becomes lighter. Our allies and partners provide complementary capabilities and forces along with unique perspectives, regional relationships, and information that improve our understanding of the environment and expand our options. Allies and partners also provide access to critical regions, supporting a widespread basing and logistics system that underpins the Department’s global reach.”

During FY 2018, INDPOL led and/or supported multiple initiatives to strengthen alliances and attract new partners. The following are INDPOL's main accomplishments in this area for the recent year:

- The Assessments group led a 2018 Nuclear Posture Review Implementation task to perform an industrial base assessment for nuclear systems.
- The Assessments group led one of the efforts under the new and updated U.S. Conventional Arms Transfer Policy to support allies and partners, as outlined in National Security Presidential Memorandum (NSPM-10). This effort's goal is to increase production capacity and reduce Foreign Military Sales (FMS) acquisition timelines.
- The Assessments group led the effort to obtain a Security of Supply Arrangement (SOSA) with the country of Norway. A SOSA is a bilateral agreement that allows DoD to request priority delivery for contracts, subcontracts, or orders from companies in a country and allows the signatory nation to request priority delivery for its contracts and orders with U.S. firms. These arrangements strengthen our alliances by providing a mechanism to ensure mutual supply of defense goods and services. Currently, DoD has SOSAs with eight countries.*
- As part of the EO 13806 assessment, the Policy and Outreach group conducted briefings on the EO 13806 efforts with allied governments to discuss industrial base risks of mutual concern and open dialogue for collaborative solutions.
- Through engagement with international industry partners and with other governments, the Policy and Outreach group refined and solidified industrial base efforts. In FY 2018, INDPOL attended the Farnborough Air Show (Farnborough, United Kingdom (U.K.)) with the Assistant Secretary of Defense for Acquisition as the lead representatives for the Office of the Secretary of Defense (OSD). Engagements at Farnborough focused on U.K.-based companies currently or potentially working with U.S.-based suppliers; a number of follow-on engagements from the show enhanced interoperability and collaboration with our British allies.
- The National Technology and Industrial Base (NTIB) nations—Canada, the U.K., Australia, and the United States—explored activities to further enhance industrial base partnership and defense activities among the four nations. Throughout 2018, the NTIB countries, led by INDPOL's Policy and Outreach group, developed a statement of principles and strategic framework for pilot projects against which to evaluate the NTIB construct. During 2019, the NTIB countries agreed to down-scope the pilot projects and focus on two key areas—foreign direct investment and technology transfer. In February 2019, the

* Australia, Canada, Finland, Italy, the Netherlands, Sweden, Spain, the United Kingdom, and Norway.

NTIB principals met after the Avalon Air Show (Geelong, Australia) to evaluate the progress of the two pilot projects and determine how to expand their engagements to other areas of mutual concern.

- In June 2018, INDPOL leadership visited Israel to discuss the status of the U.S.–Israel relationship and better understand the desires of the Israeli government and industry to work with the United States. The Office is working closely with partners from the Office of the Under Secretary of Defense for Policy (OUSD(Policy)), the International Cooperation (IC) Directorate in the Office of the USD(A&S), the Defense Technology Security Administration, and the Defense Security Cooperation Agency to align U.S.–Israeli conversations to areas of mutual effort and support upcoming leadership engagements in the spring of 2019.
- In 2018, INDPOL became the lead for Indian defense industry activities under the Defense Technology and Trade Initiative (DTTI). Initiated in 2012 by the Secretary of Defense, DTTI provides senior leaders from the United States and India a construct upon which to discuss opportunities and challenges associated with expanding the U.S.–Indian defense partnership. The Office’s role as lead for engagements with Indian industry will help further these goals and facilitate communication between DoD, the Indian government, and members of India’s defense industry. As part of this effort, INDPOL and the Deputy Under Secretary for Acquisition and Sustainment (DUSD(A&S)) attended Aero India in Bangalore (February 2019).
- The GMI group is working with the Department of the Treasury to establish a formal process for the exchange of CFIUS information with our allies. Per FIRRMA, the information sharing process will be designed to “facilitate the harmonization of action with respect to trends in investment and technology that could pose risks to the national security of the United States and countries that are allies or partners of the United States.” The group traveled to the U.K., Canada, Australia, New Zealand, Japan, and South Korea in support of bilateral discussions concerning FDI review processes, and supported local meetings with Taiwan authorities and representatives of the European Union. Additionally, GMI provided briefings and support to the Department of State–hosted Multilateral Action for the Protection of Sensitive Technology conference, which included 13 country delegations.

2.3. Reform the Department of Defense for Greater Performance and Affordability

The NDS recognizes the need to institute business reforms to improve performance and increase affordability. The FY 2018 NDS states:

“We will put in place a management system where leadership can harness opportunities and ensure effective stewardship of taxpayer resources. We have a responsibility to gain full value from every taxpayer dollar spent on defense, thereby earning the trust of Congress and the American people.”

2.3.1. Changes to DoD Organizational Structure

In FY 2018, DoD implemented a new organizational structure that established an USD(R&E) and an USD(A&S) in place of the Under Secretary of Defense for Acquisition, Technology, and Logistics (USD(AT&L)). As part of the restructure, INDPOL reports directly to USD(A&S).

USD(R&E) created the office of Technology and Manufacturing Industrial Base (TMIB). This office serves as the principal advisor to the USD(R&E) on the Technology and Manufacturing Industrial Base, the National Manufacturing Institutes, and the ManTech program. TMIB oversees the development of advanced manufacturing technologies for the DoD modernization priorities and other critical defense requirements, and identifies nascent research supply chain gaps, which when addressed, will accelerate the speed of innovation. This new office complements the INDPOL office mission to support a healthy and resilient industrial base. Prior to the reorganization, the National Manufacturing Institutes and ManTech program resided in the INDPOL office.

As part of USD(R&E), the DoD ManTech program addresses near term critical technology requirements and accelerates promising technology to the warfighter via innovative manufacturing methods through a two-pronged strategy: (1) OSD ManTech R&D projects and (2) the Manufacturing Innovation Institutes.

The DoD ManTech program accelerated the adoption of advanced manufacturing via the eight advanced manufacturing public-private partnerships. A strategy was published to guide DoD Manufacturing Education and Workforce Development (EWD) investments, with over 200,000 students and educators benefiting from the current ManTech EWD programs established. ManTech also established the

National Center for Cybersecurity for Manufacturing at the Digital Manufacturing and Design Innovation Institute in Chicago.

The program is coordinating with Australia's defense organization to explore ways to partner in the area of cyber security for manufacturing, particularly in support of small businesses. The ManTech office also continued to interact with the U.K.'s High Value Manufacturing organization to share best practices and lessons learned on each country's manufacturing innovation institutes. The public-private partnerships established by the manufacturing innovation institutes continue to provide pathways to adapt commercial technologies to defense applications.

This report includes DoD ManTech activities in support of the NDS and the risk mitigation strategies identified during the EO 13806 assessment. INDPOL will continue working closely with USD(R&E) in support of new technology developments and the health of the associated industrial base and research base.

2.3.2. Business Reforms to Improve Performance and Increase Affordability

During the year, INDPOL took proactive steps to improve its businesses processes in support of DoD and all the components of the DIB. The steps taken are listed below:

- Within the Title I program, restructuring of the DPAS process was initiated with the goal of managing the program more effectively. This provided a more responsive process to address national security requirements, including an enterprise-level approach to evaluate "DX" ratings*, and assigning resources to mitigate competing cross-service requirements.
- The GMI group took a leading role with the Department of the Treasury in the shaping of the FIRRMA legislation, and continues to facilitate its implementation. Although some portions of FIRRMA were enacted immediately, GMI worked with Treasury to create a pilot program that issued temporary regulations to protect critical U.S. technology and intellectual property from potentially harmful foreign investments/acquisitions. The GMI group subsequently created a robust process with its DoD stakeholders to review the cases associated with the pilot program filings. The pilot programs allow for input from industry and are a critical component of improving the process going forward—not just for DoD, but also for the security of industry.

* A DX rating is assigned to those programs of the highest national defense priority and is approved by the Secretary of Defense or Deputy Secretary of Defense.

- The GMI group is building a systems-based approach to CFIUS operations and review as a result of the FIRRMA legislation. These new systems and process changes will enable DoD to flag questionable transactions earlier while also building in metrics to recognize allies and partnerships, sparing resources for the highest risk transactions, and granting a reduced burden on our most trusted allies.
- The OSBP group continues to improve business processes within the DoD acquisition community. In 2018, the OSBP group partnered with the Small Business Administration (SBA) to host the 2018 Small Business Training Week, which trained over 700 DoD and SBA professionals. Additionally, the OSBP group hosted the Mentor Protégé-Beyond Phase II Conference, which brought together the Mentor Protégé, Small Business Innovative Research, and Rapid Innovation Fund programs to collaborate and educate government and industry on industrial base challenges, program opportunities, and how these programs can work to address critical technology areas and capability gaps. Additionally, the OSBP group worked with the SBA to host two ChallengeHER events as part of a national initiative to boost government contracting opportunities for women-owned small businesses with a special focus on the Women-owned Small Business Federal Contracting Program.
- The OSBP group plays a pivotal role in creating and implementing business reforms aimed at simplifying and streamlining the acquisition process. This effort serves to broaden and diversify the Defense Industrial and Technology Base and enable more small businesses to work with DoD. In FY 2018, in response to legislation in the FY 2013 NDAA, the OSBP group worked the federal rulemaking process for a class deviation on implementation of the limitations on subcontracting to better align with the SBA's approach to subcontracting. The issued deviation serves to bridge the gap between SBA's regulations and the corresponding Federal Acquisition Regulations yet to be finalized. In doing so, the deviation, like the SBA regulations, dramatically simplifies the self-performance requirements, giving contractors greater certainty when attempting to ensure compliance, and restricts the percentage of the total award that can be passed on to subcontractors.
- Throughout 2018, Policy and Outreach conducted a number of engagements with industry—from trade associations and prime contractors to the investment community and tech companies—to better understand the challenges in doing business with DoD. The output of these engagements informed DoD acquisition reform efforts.
- To support DoD's goal to create an organizational structure that provides technical superiority and weapon systems affordability, OSD leads multiple working groups, committees, and Integrated Product Teams (IPTs) to share information between government stakeholders and industry, identify and

prioritize risks, and accelerate the implementation of risk mitigation strategies. The following working groups, with the lead or co-chair office identified, were supported this year:

1. Critical Energetic Materials Working Group (CEMWG)—INDPOL Oversight: The single focal point for DoD for availability and obsolescence issues for critical chemicals. The working group assesses risk of supply for these chemicals, and develops and implements mitigation plans for these risks, and also for issues when they develop. Funding for mitigations comes from OSD IBAS, DPA Title III, and ManTech investment programs, as well as Service funding from acquisition program offices.
2. Cybersecurity for Manufacturing Government Advisory Committee—ManTech Co-chair: This committee is co-chaired with the National Center for Cybersecurity in Manufacturing, housed within the Manufacturing times Digital (MxD) manufacturing innovation institute. As a public-private partnership, this committee ensures that all stakeholder equities from the government to industry to academia are recognized, fed into a strategic roadmap, and considered for investment across the public-private partnership.
3. Joint Additive Manufacturing Steering Group (JAMSG)/Joint Additive Manufacturing Working Group (JAMWG)—TMIB/ManTech Chair: The JAMSG, with the support of the JAMWG, develops the DoD-wide additive manufacturing (AM) strategy, produces necessary policy and guidance to the Services and Defense agencies, identifies and shares AM best practices and AM development and adoption information, and supplies funding and guidance toward a joint AM investment strategy.
4. Joint Army–Navy–National Aeronautics and Space Administration (NASA)–Air Force (JANNAF) Interagency Propulsion Committee’s Programmatic and Industrial Base (PIB) Committee—INDPOL Co-chair: JANNAF is a forum for industry-government collaboration and information sharing on issues facing the missile propulsion industrial base.¹ Key DoD and NASA decision points that may affect the IB, as well as IB issues, are brought to the attention of senior DoD and NASA leadership for consideration/mitigation.
5. Manufacturing Education and Workforce Development Interagency Working Group—ManTech Chair: This cross-federal agency working group focuses on assessing the U.S. industrial base workforce needs, now and in the future. Based on these assessments, the group works collaboratively across federal agencies and with states and academia (trade and technical schools, community colleges, and universities) to develop a suite of educational resources and replicable educational tools and programs across a variety of advanced manufacturing technologies.

6. Space Industrial Base Working Group (SIBWG)—INDPOL Chair: The SIBWG is committed to fostering a National Security Space (NSS) industrial base perspective on critical space capabilities and fragile suppliers. The group assesses risk, develops mitigation plans, and promotes management and procurement practices within DoD and the Intelligence Community that ensure access to critical technologies in the quality, quantity, and timeframe required to meet the missions of the NSS community.
7. Subcommittee for Advanced Manufacturing (SAM)—ManTech Co-chair: This White House subcommittee is positioned under the National Science and Technology Council, Committee on Technology. The SAM is an inter-federal agency forum for information sharing, coordination, and consensus building among participating agencies regarding federal policy, programs, and budget guidance for advanced manufacturing.
8. Joint Industrial Base Working Group (JIBWG)—INDPOL Co-chair: The JIBWG brings together the Services and government agency industrial base stakeholders to share, coordinate, and collaborate on defense industrial base issues in the interest of managing limited DoD industrial analysis resources, minimizing redundancy, and having an overall view of the industrial base risks impacting multiple programs, Services, and agencies. Core members include A&S, Military Services, Defense Contract Management Agency, Defense agencies, Joint Staff, and Combatant Commands. The group meets bi-annually to share industrial base analyses executed during the year and propose new assessments necessary to help senior decision makers achieve DoD strategic objectives.
9. DoD Fuze IPT—INDPOL Co-chair: The DoD Fuze IPT was formed to establish and sustain viable U.S. Government (USG) and U.S. fuze industrial bases to provide the necessary science and technology, engineering development, test and evaluation, production, and sustainment of current and future DoD fuzes. Its vision is to enable a responsive and innovative fuze technology base, capable of meeting national security requirements, while advancing the state-of-the-art fuzing system technologies, preserving critical core competencies, and facilitating the transition of these technologies into current and future munitions. The Fuze IPT interacts with the fuze industry through the National Armaments Consortium. This group has specific directives to:
 - a. Identify issues affecting current fuze industrial and DoD competency and technology base
 - b. Determine what is required for a DoD fuze industrial and technology base and develop a strategy for reshaping the fuze base to meet the requirements
 - c. Develop and implement a plan of action and milestones for the strategy

10. Joint Munitions Power Sources (JMPS) IPT—INDPOL Co-chair: The JMPS IPT was established to provide centralized leadership and advocate for the research, development, and production of reliable munitions power sources to meet current and future warfighter needs. The IPT fosters a community of munitions power expertise, and implements the best available technology and production practices to spearhead advancements in power capabilities and enable enhanced munitions performance. The IPT is tasked to:
- a. Identify issues affecting the current munitions power source technical and industrial bases, as well as the current DoD munitions power source capability, technology, and effectiveness
 - b. Identify issues and challenges affecting munitions power source components and chemistries
 - c. Develop government in-house and commercial industrial base competencies to address technical gaps, such as manufacturability of small munitions batteries
 - d. Develop a strategy to address current and future power requirements
 - e. Develop and implement a plan of action and milestones for the strategy

3. Defense Industry Outlook

3.1. The Defense Industrial Base is Profitable and Expanding

The U.S. aerospace and defense (A&D) sectors continue to outperform the broader U.S. equity market, suggesting investors remain optimistic about the overall health, profitability, and long-term prospects of the sector (Figure 2).

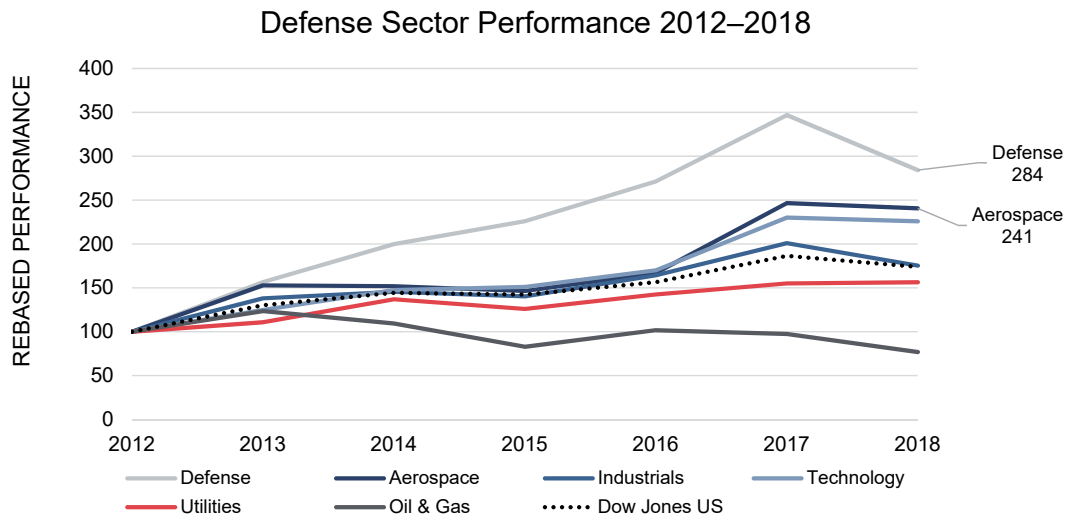


Figure 2. Stock Performance Trend by Market Sector [CY 2012–CY 2018] (2012 baseline)

3.2. Supplier Assessment

Overall, major defense suppliers have been able to remain financially healthy while expanding market share. Major suppliers of defense products and services are profitable, showing positive earnings before interest, tax, depreciation, and amortization (EBITDA) margins (shown in Figures 3A and 3B). Major defense

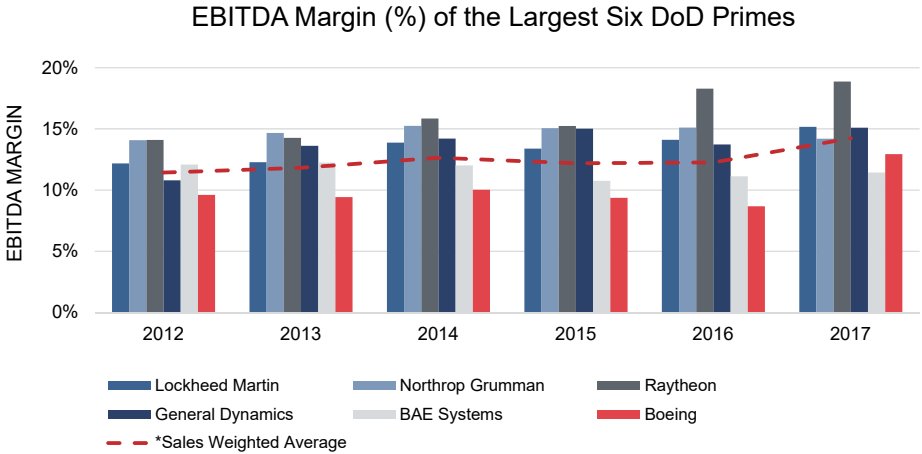


Figure 3A. EBITDA Margin (%) of the Largest Six DoD Primes [CY 2012–CY 2017]

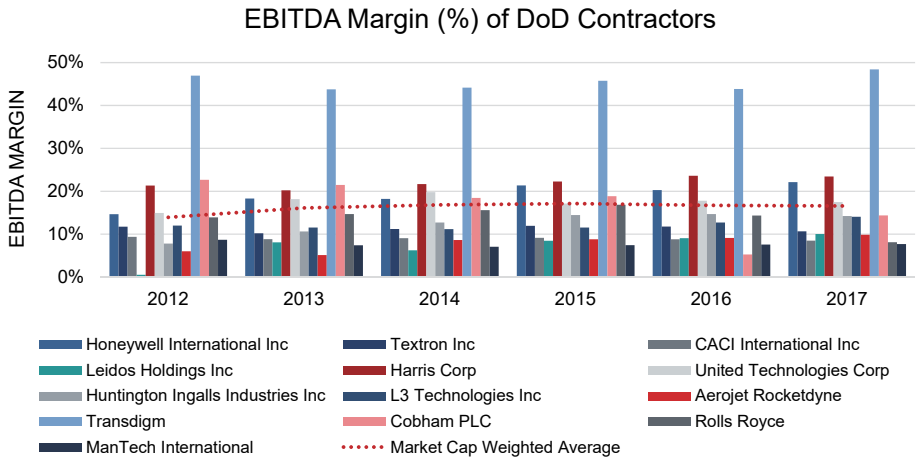


Figure 3B. EBITDA Margin (%) of DoD Contractors [CY 2012–CY 2017]

suppliers have seen growing demand for their products and services, driving higher sales and greater scale, helping to reduce costs and boost competitiveness. However, to maintain top line growth and mitigate the cyclical nature of U.S. defense spending, some firms will continue to diversify their customer base and pursue international and non-defense customers. The “Big 6” defense contractors

(Lockheed Martin, Boeing, Northrop Grumman, Raytheon, General Dynamics, and BAE Systems) have seen a rise in non-defense revenue (shown in Figure 4), and there is growing demand in international markets for the Patriot system² and the F-35 aircraft.³ Higher U.S. defense spending in FY 2019 may alter that trend, as U.S. firms respond to higher U.S. demand and altering global trade patterns.

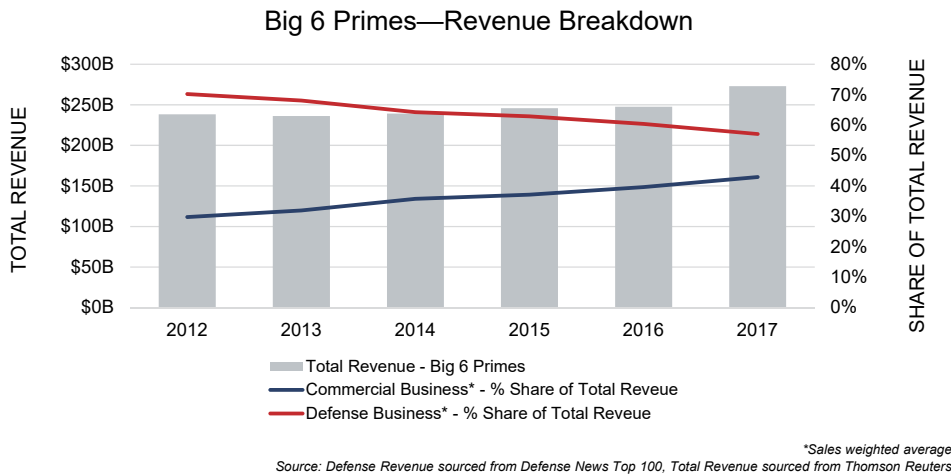


Figure 4. Big Six Defense Contractors—Revenue Breakdown [CY 2012–CY 2017]

In addition to an expanding market, major defense suppliers remain profitable as they have increased earnings per share over the last 10 years. The greater level of operating efficiency has played a key role in generating more cash from operations for defense companies, making them more likely to self-fund business activities such as capital expenditures, research and development, and acquisitions.

3.3. Changes in DoD Obligations and Vendor Composition

The Department’s contract obligations have maintained a near even split between products and services since FY 2012 (Figure 5); however, the total number of

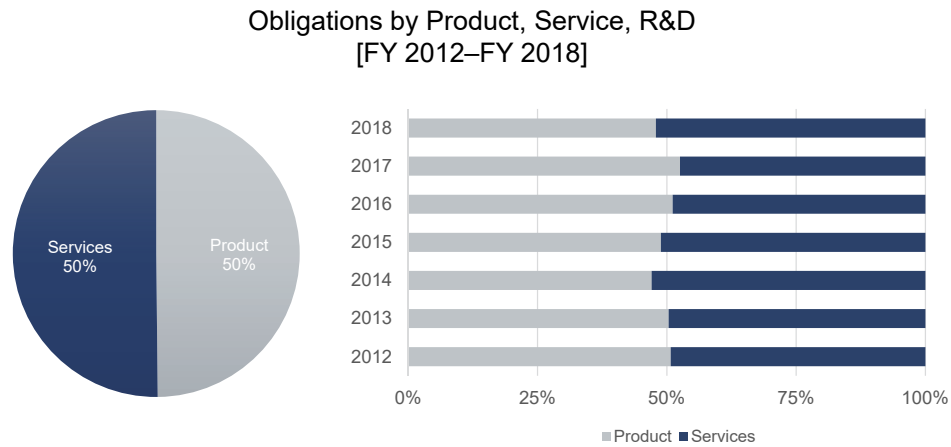


Figure 5. Obligation by Product and Service [FY 2012–FY 2018]

vendors participating in key DoD sectors is declining (Figure 6). The defense

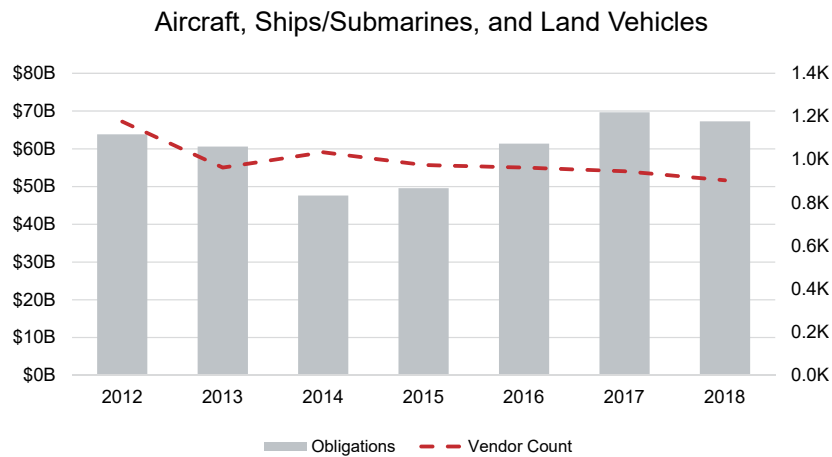


Figure 6. Aircraft, Ships/Submarines, and Land Vehicles [FY 2012–FY 2018]

sector is characterized by relatively high barriers to entry (e.g., technical experience and skilled labor, navigating the acquisition process, security compliance, and capital-intensive infrastructure requirements). Aircraft, ships, submarines, and land vehicles comprise the department’s largest acquisition portfolio and also

have some of the highest barriers to entry, suggesting that, absent a concerted effort, DoD could find it difficult to attract new entrants and ensure a competitive market capable of meeting its evolving needs. This trend is not isolated to the capital-intensive activities such as aircraft and ships. Despite total dollars spent (obligations) on weapons and ammunition increasing year-over-year since 2016, the number of vendors in that portfolio has decreased.⁴ Even in the defense services market, which is traditionally considered to have lower barriers to entry, supplier counts are shrinking.

Globally, A&D companies are among the lowest research and development (R&D) spenders. In absolute numbers, the global A&D industry spends much less on research and development than other critical sectors. In terms of innovation intensity (the percentage of sales earmarked for R&D), spending is also comparatively low at 4.1%, trailing other sectors.⁵ Although scales and time frames (fiscal year vs. calendar year) differ between DoD budgeting and corporate spending, a rebased trend plot shows that expenditures on R&D by the “Big 6” defense contractors closely track DoD research, development, testing, and evaluation (RDTE) spending (Figure 7). This implies that defense suppliers rely

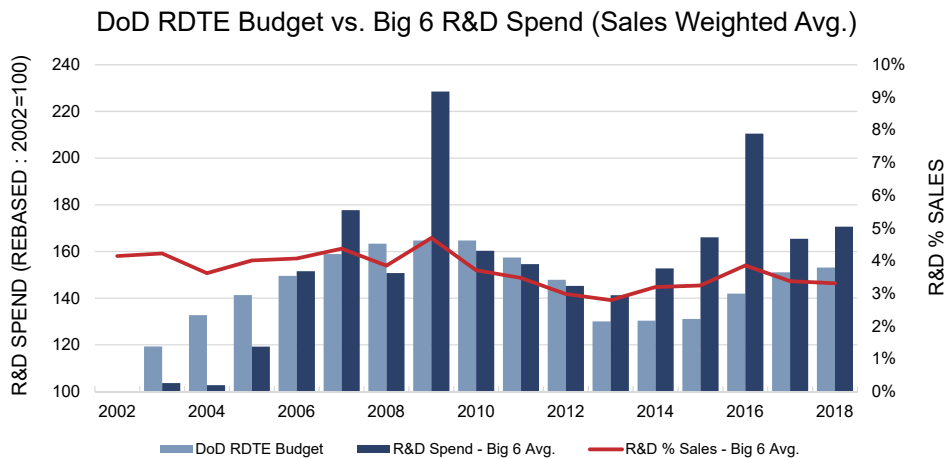


Figure 7. DoD RDTE Budget vs. Big 6 R&D Spend (Sales Weighted Avg.)

on the guidance provided by DoD to drive development of newer technologies and capabilities.

Historically, most investment by defense firms has been directed toward capital expenditures (CAPEX) and M&A. The “Big 6” defense contractors have primarily been focused on CAPEX and smaller bolt-on acquisitions, whereas mid-size suppliers have historically spent more on M&A. The previous year showed renewed

M&A activity, with combinations of large defense suppliers such as Northrop Grumman and Orbital ATK driving the trend.

3.4. Outlook and Challenges

Industry should experience continued growth as DoD budget authority for operation and maintenance (O&M), procurement, and RDT&E increases. A concerted USG effort has prioritized strengthening the nation’s military, with a focus on modernization and greater lethality. Accordingly, the bulk of the budgeted spending is allocated to O&M followed by procurement spending (Figures 8, 9,

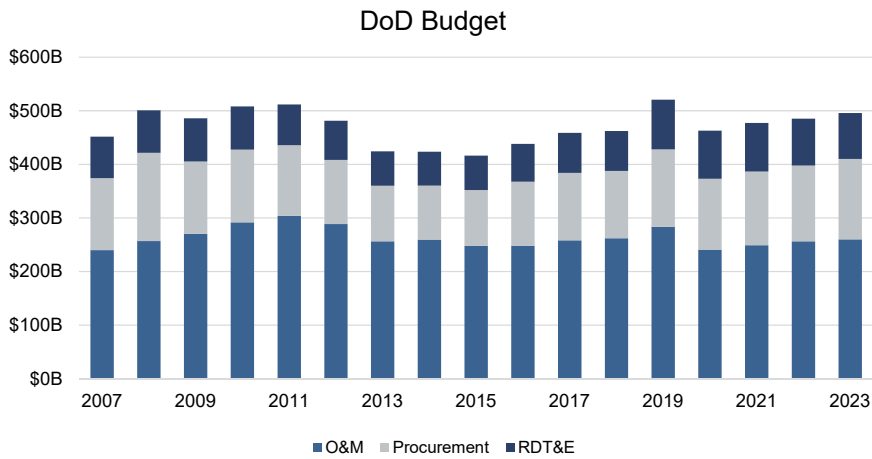


Figure 8. DoD Budget Authority—RDT&E, Procurement, O&M [FY 2007–FY 2023]

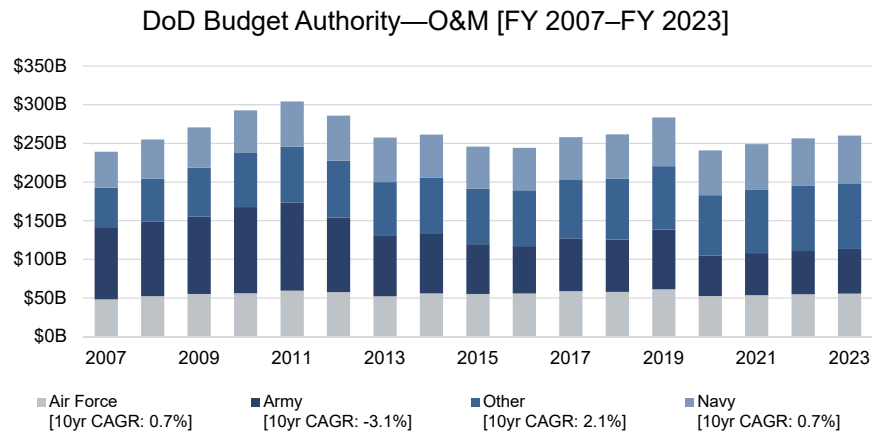


Figure 9. DoD Budget Authority—O&M [FY 2007–FY 2023]

10, and 11). Aircraft, primarily the F-35, will play a major role in the future of the defense industry.⁶ Ships and ground vehicles will remain key components of the U.S. modernization effort. Space and cybersecurity became significantly more important, and will continue to attract attention as the United States continues to prevent cyber attacks. The United States is also encouraging allies, such as the North Atlantic Treaty Organization nations, to increase defense budgets to defend against potential threats. This, coupled with a greater emphasis on FMS, will help drive international sales for major U.S. defense suppliers, and help them continue to diversify revenue streams.

Budget Authority—Procurement [FY 2007–FY 2023]

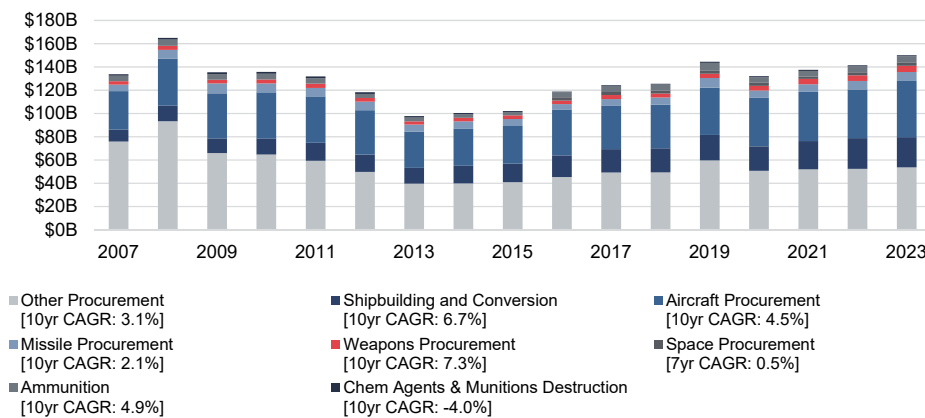


Figure 10. DoD Budget Authority—Procurement [FY 2007–FY 2023]

DoD Budget Authority—RDT&E [FY 2007–FY 2023]

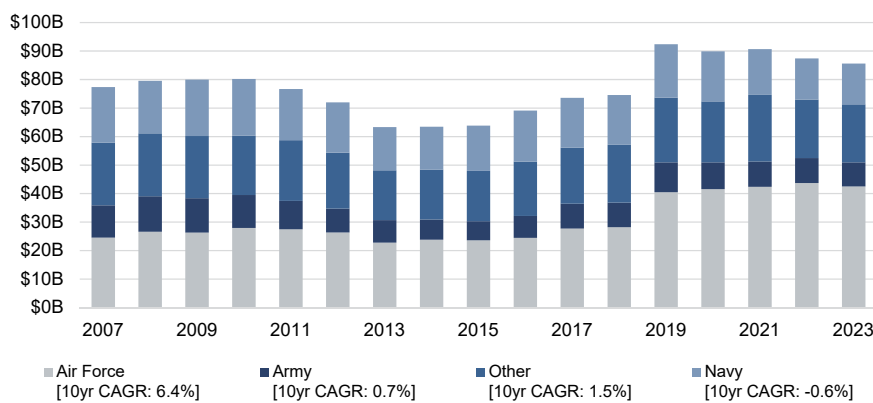


Figure 11. DoD Budget Authority—RDT&E [FY 2007–FY 2023]

4. U.S. Position in the Global Defense Markets

4.1. United States Contribution to Global Defense Spending

Global military spending continues to grow, expanding from \$1.3 trillion in 2008 to \$1.7 trillion in 2017. The United States continues to be the main source of defense spending and accounted for ~36% of global defense spending in 2017. U.S. defense spending increased from \$557 billion in 2007 to \$610 billion in 2017. The second largest military spender is China, which doubled its spending from ~\$100 billion in 2007 to \$228 billion in 2017.⁷ Beyond China and the United States, defense spending grew from ~700 billion in 2007 to ~900 billion in 2017,⁸ led by Saudi Arabia, Russia, India, France, the U.K., Germany, Japan, and South Korea.⁹ Figure 12 illustrates the annual military spending of the United States, China, and the rest of the world. As spending grows, defense firms globally are poised to capitalize on this trend.

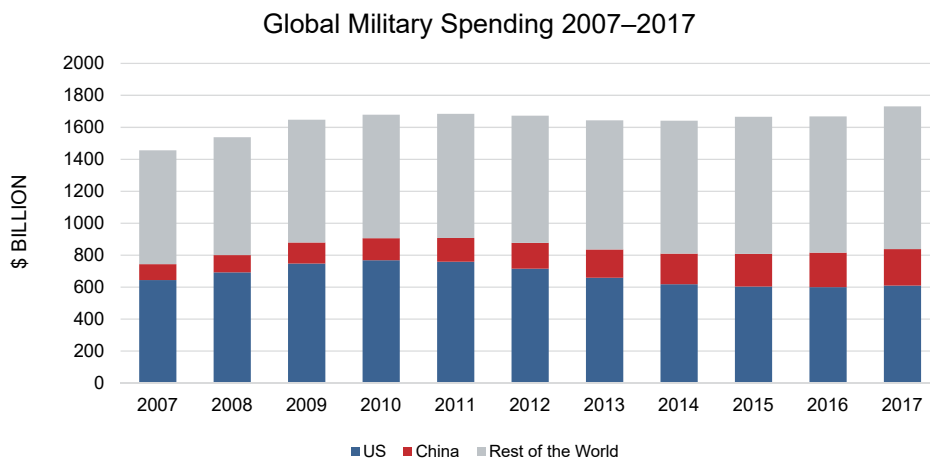


Figure 12. Global Military Spending [CY 2007–CY 2017]

4.2. Defense Exports and Foreign Military Sales

The United States remains the leading defense exporter and the USG is emphasizing efforts to increase the efficiency of the FMS process to ensure that the United States will continue to meet strong demand. In FY 2018, FMS increased 33% from FY 2017 to \$55.66 billion.¹⁰ Significant deals completed in 2018 include \$6.5 billion for littoral combat ships for Saudi Arabia,¹¹ \$5.1 billion for F/A-18 aircraft for Kuwait,¹² and \$4.6 billion for Patriot air and missile defense systems for Poland.¹³

Demand for combat aircraft remains strong. The United States delivered 200 combat aircraft in 2013–2017.¹⁴ These deliveries included a total of 50 F-35 combat aircraft to the following nations: the U.K. (12 F-35s), Norway (10 F-35s), Italy (9 F-35s), Israel (9 F-35s), Japan (6 F-35s), Australia (2 F-35s), and the Netherlands (2 F-35s).¹⁵

However, while overall exports may be increasing, the United States has lost some ground in other defense sectors. Most notably, the United States has seen its market share of global Naval Weapons exports decrease from 63% in 2007 to 17% in 2017.¹⁶ Additionally, over the last 10 years the United States has seen a decrease in exports to countries that traditionally imported from the United States.¹⁷ For example, Pakistan (31%) and South Korea (78%) imported the majority of their defense goods from the United States between 2008 and 2012. The share of exports from the United States dropped in both Pakistan (12%) and South Korea (53%) from 2013 to 2017, primarily as a result of Germany and China increasing defense exports to those countries.¹⁸

In FY 2018, the administration released a National Security Presidential Memorandum, which commits the USG to “advocate strongly on behalf of United States companies” and “streamline procedures, clarify regulations, increase contracting predictability and flexibility, and maximize the ability of the United States industry to grow and support allies and partners.”¹⁹ Soon after the memorandum’s release, the Defense Security Cooperation Agency reduced the FMS Administrative Surcharge, which immediately lowered costs for international partners.²⁰ These efforts to increase the efficiency of the FMS process ensure that the United States will continue to meet strong demand for defense platforms and systems, while incentivizing future growth.

4.3. Competitor Nations

China has emerged as a major defense manufacturer and is home to large defense firms such as China South Industries Group Corporation (CSGC), China Aviation Industry Corporation (AVIC), and China North Industries Group Corporation (NORINCO) (Figure 13).²¹ Chinese defense manufacturers have grown quickly, with seven companies exceeding \$5 billion in revenue in 2016.²² In one exceptional case, the revenue of the second leading Chinese defense firm (AVIC) has grown 93% over the last decade (from \$31 billion in 2007 to \$59.7 billion in 2017).²³

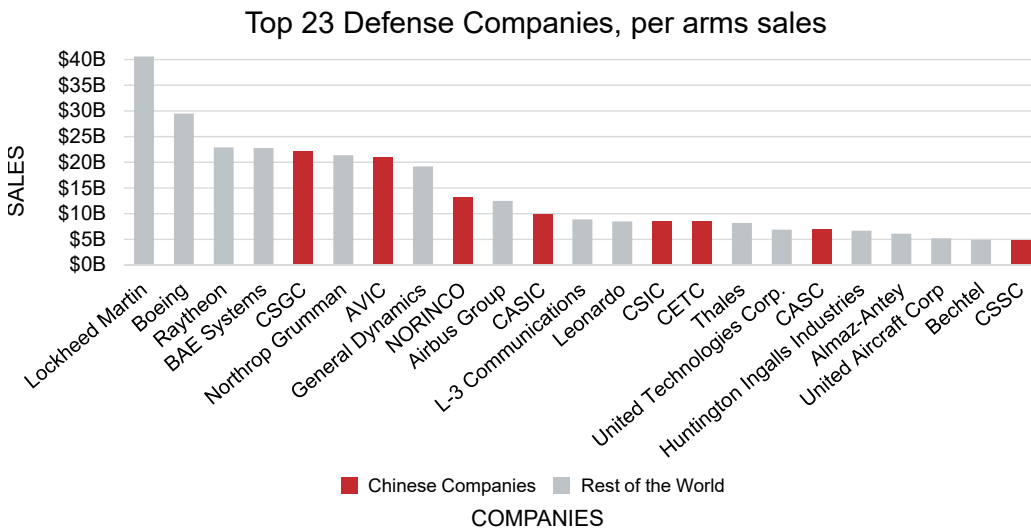


Figure 13. Top 23 Defense Companies per Arms Sales (CY 2016) Billions USD

In 2017, China exported \$2.41 trillion worth of goods and services. China’s top exports were broadcasting equipment, computers, office machine parts, integrated circuits, and telephones. The country’s major export destinations are the United States, Hong Kong, Japan, Germany, and South Korea.²⁴

China’s top imports include integrated circuits, crude petroleum, iron ore, cars, and gold. The United States, Japan, Germany, and South Korea are among the country’s main importers.

China has developed a strategic plan—Made in China 2025—to become the world leader in manufacturing and technology. The country has become one of the largest global players in technology areas like quantum computing and 5G technology, and is investing in biotechnology and space research.²⁵

Russia remains the second largest exporter of arms behind the United States. Russia sold nearly \$15 billion of weapons to over 50 nations in 2017.²⁶ About

\$6 billion of that was for major defense platforms, including aircraft, ships, armored vehicles, and guided munitions.²⁷ Russia represented 26% of global arms exports from 2008–2013. Several countries rely on Russian military imports, including Vietnam (82% of arms imports come from Russia), China (65%), India (62%), and Algeria (59%).²⁸ Russia is also reliant on these four countries as they make up four of the top five buyers of Russian arms (see Figure 14).

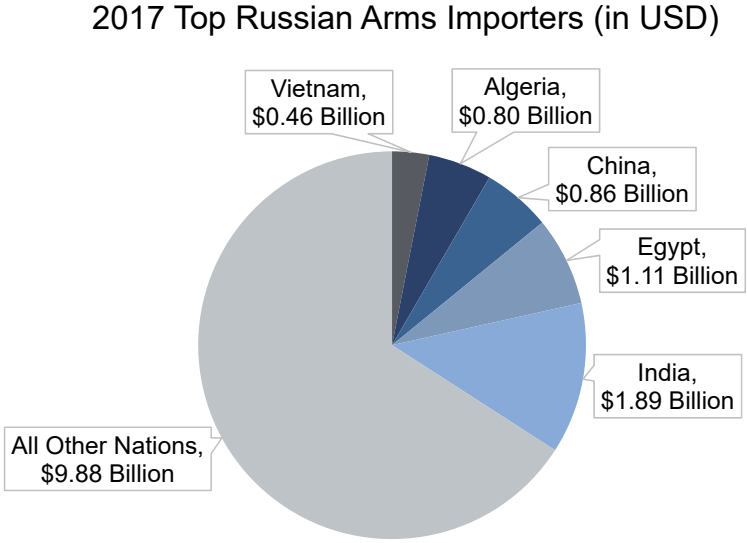


Figure 14. 2017 Top Russian Arms Importers



5. Executive Order 13806—Assessing and Strengthening the Manufacturing and Defense Industrial Base and Supply Chain Resiliency of the United States

On July 21, 2017, President Trump issued EO 13806 on Assessing and Strengthening the Manufacturing and Defense Industrial Base and Supply Chain Resiliency of the United States. The EO directed the Secretary of Defense to perform a whole-of-government assessment of the manufacturing and DIB, assess risk, identify impacts, and propose mitigations.²⁹ The assessment was ordered with the recognition that in a renewed era of great power competition, the ability to arm our warfighters with the lethality and dominance to meet new and unforeseen strategic challenges is dependent upon a healthy and resilient DIB.

On October 5, 2018, Deputy Secretary of Defense Shanahan delivered the EO 13806 report and action plan to the President. The effort, led by the INDPOL office and chaired by the White House Office of Trade and Manufacturing Policy, assembled over 300 experts from within DoD and across the government to participate in the Interagency Task Force (ITF). The Departments of Commerce, Labor, Energy, Homeland Security, 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; and multiple organizations across DoD participated in the assessment.

The EO 13806 effort focused on assessing the health of the DIB as related to the operating priorities of the Department from July 2017 to April 2018, which mainly included counterterrorism activities. During the course of the assessment, the NDS was released, and its shift to a great power competition provides the construct for the follow-on efforts of EO 13806.

The three lines of effort outlined in the NDS—lethality for the warfighter, strengthening alliances and partnerships, and business reform—all require a healthy, robust, and secure industrial base. Without a strong defense industry and healthy manufacturing sector, both domestic and with foreign allies and partners,

DoD cannot ensure national security. All of the current and future activities of the EO 13806 effort directly support the NDS priorities.

In scoping the EO 13806 effort, DoD focused the assessment on 16 working groups—nine in “traditional” sectors (e.g., aircraft, ground systems, etc.) and seven for “cross-cutting enablers” (e.g., electronics and workforce), as outlined in Figure 15.

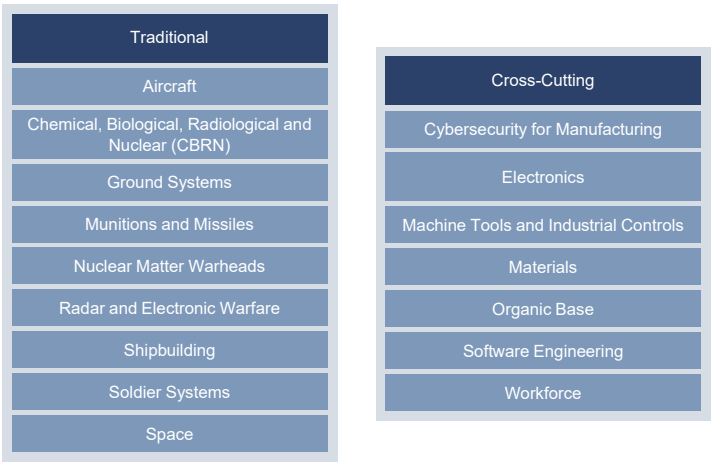


Figure 15. List of Traditional and Cross-Cutting Sectors

The framework used for the EO 13806 effort, outlined in Figure 16, provided a construct to determine risks in the DIB. Across the 16 working groups (outlined above), nearly 300 impacts were identified.

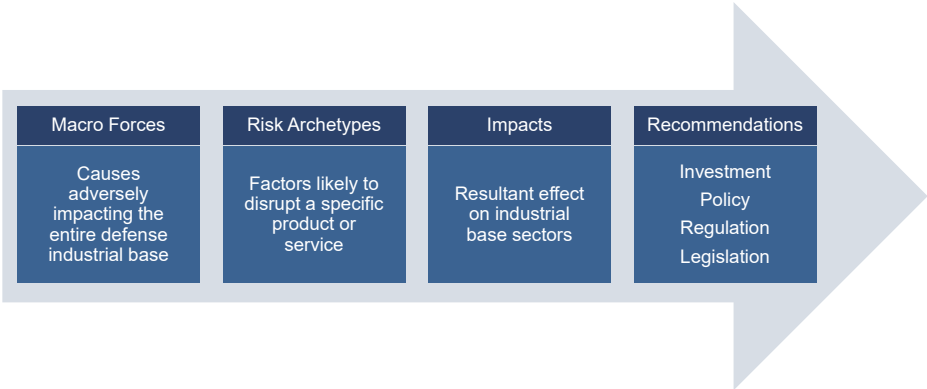


Figure 16. Manufacturing and Defense Industrial Base Risk Framework

The results of the assessment concluded that there are five macro forces (defined in Table 1) impacting the industrial base, which cause 10 main risk archetypes (defined in Table 2). Multiple macro forces can create one risk archetype, or one macro force can cause multiple risk archetypes to exist. The dynamic mapping of macro forces to risk archetypes aligns to the dynamism of the 21st century DIB. The macro forces identified during the risk assessment outlined long-term trends driving risk into the DIB. While each macro force may individually be addressed and mitigated against, the combination of all five macro forces working simultaneously over time creates deeper risk trends in the industrial base. Risk mitigation activities focus on addressing the macro forces to foster a more secure DIB.

Table 1. Definitions of the Five Macro Forces Driving Risks into America's Industrial Base

MACRO FORCES	DEFINITION
Sequestration and uncertainty of USG spending	Inconsistent appropriations, uncertainty about future budgets, macro-level ambiguity in USG 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 USG business and procurement practices	Challenges working with DoD and other USG customers, including contracting regulations, policies, barriers to entry, qualification challenges, programmatic changes, and other problems, can lead to adverse effects on suppliers
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. science, technology, engineering, and mathematics (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

Table 2. Ten Risk Archetypes Threatening America's Manufacturing and Defense Industrial Base

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

RISK ARCHETYPE	DEFINITION
Diminishing manufacturing sources and material shortages	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

As part of the EO 13806 report, the ITF created an action plan that includes recommendations designed to mitigate the most critical impacts as of April 2018. The ITF reconvened in October 2018 to start implementation of the action plan, including updates to identified risks and appropriate mitigations. Many of the impacts identified within each of the sectors aligned to multiple sectors, so the ITF is taking a strategic approach to risks and proposed mitigations to ensure the greatest impact. In addition, INDPOL is shifting industrial base assessment activities from a counter-terrorism focus to a great power competition focus, in alignment with the NDS.

The annual industrial capabilities report will provide Congress with updates related to the implementation and execution of the industrial base risk mitigation strategies and follow-on efforts. This year the report provides a summary of all the traditional and cross-cutting sectors assessed, and mitigation strategies to be implemented in FY 2019.



5.1. Aircraft

5.1.1. Sector Overview

The aircraft sector is divided in three subsectors: fixed wing, rotorcraft, and unmanned aerial systems required for air-to-air and air-to-ground military operations and transport. 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.

5.1.2. Sector Risks and Mitigation Strategy

The aircraft sector faces challenges, including long product/system development timelines, high development and qualification costs, and production limitations. Consolidation of prime suppliers in the sector 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.

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 start 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 (DARPA) 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.

Software skills are also a critical issue for the aircraft sector. In fourth-generation fighters, software made up about 15% of the total engineering of the aircraft. In fifth-generation fighters, software now accounts for over 40% of the engineering of the aircraft. It is becoming increasingly difficult to hire skilled, cleared, and capable software engineers. As aircraft continue to increase in software complexity, it will become even more important for the sector to hire skilled software engineers. America Makes, a DoD sponsored manufacturing innovation institute overseen by the ManTech program, is also accelerating the implementation of additive manufacturing, in particular within the Air Force sustainment functions by providing pathfinding expertise and training.

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 cyclical nature 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 or alternate 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.

Programs like the next-generation bomber (B-21), the aerial-refueling tanker (KC-46 Pegasus), the joint strike fighter (F-35), the MQ-25, and future rotorcraft modernization projects are partially addressing the workforce risks. The Aircraft Working Group is focusing on addressing risks related to single and sole source suppliers in the supply chain that may impact multiple aircraft programs. The group is working on deep-dive analyses to select options to mitigate risks in areas like materials, aircraft components, and skill shortages.



5.2. Chemical, Biological, Radiological, and Nuclear

5.2.1. Sector Overview

The chemical, biological, radiological, and nuclear defense (CBRND) sector provides capabilities through the integration of science, engineering, testing, and logistics to field products that provide protection from threats and attacks. Products include medical countermeasures to address CBRND and emerging infectious disease 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 sector is composed of commercial and organic industry of all sizes. The CBRND sector is heavily dependent upon DoD procurements for sustainability.

5.2.2. Sector Risks and Mitigation Strategy

Due to the highly technical and defense-unique nature of the CBRND products, this sector is highly dependent on single and sole source manufacturers. In many scenarios, this industrial capability constraint can be directly related to inconsistent funding and a lack of STEM skills in the workforce. The main challenge rests in working with DoD barriers that restrict entry and present qualification challenges resulting in secondary and third-order effects that limit competition within the base.

The case studies below illustrate how a capacity-constrained supply market and the erosion of U.S.-based infrastructure create gaps in the sector that may lead to limited or non-existent domestic industrial capabilities to support the NDS.

ASZM-TEDA1 Impregnated Carbon

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. ASZM-TEDA1 is used in 72 DoD chemical, biological, and nuclear filtration systems, and the current sourcing arrangements cannot keep pace with demand. The Department is exercising DPA Title III to modernize the sole production line and establish an additional source of this critical material.

Organic Industrial Base—Center of Industrial and Technical Excellence

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.

In order to reduce the effects of a fluctuating demand for CBRND products, DoD must proactively manage these critical assets using a joint approach. This effort should allow for the development of an innovative methodology for centralized management of CBRND equipment, support a holistic effort to develop a robust capital investment strategy, and evaluate the benefits of establishing the Joint/Army Chemical Biological Defense Logistics Center for centralized management.

The CBRND Working Group will continue evaluating ways to efficiently provide CBRND products to the warfighter while promoting competition and innovation in the sector. Some of the potential options to consider are support and/or expansion of current capabilities, use of alternate technologies to meet mission requirements, establishment of organic capabilities, use of authorities to sustain capabilities or prioritize defense orders, and use of non-domestic suppliers. DPA Title III is one of the authorities DoD has to expand production capacity and attract new entrants in this sector.



5.3. Ground Systems

5.3.1. Sector Overview

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. A small set of prime suppliers engaged solely in production for both tracked and wheeled vehicles defines the ground systems sector. There are two main suppliers for tracked tactical vehicles—one supplier specializing in steel fighting vehicles and another specializing mostly in aluminum armored vehicles. Production of wheeled combat service support vehicles is considered defense unique. The industrial base supporting this subsector and the U.S. automotive market is highly integrated through complex supply chains, research and development operations, and shared assembly and production systems for component manufacturing. Two domestic suppliers dominate tactical wheeled vehicle manufacture, but there are multiple qualified vendors for the repair, refurbishment, and modifications business.

5.3.2. Sector Risks and Mitigation Strategy

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. This resulted in a generation of engineers and scientists that lack experience in conceiving, designing, and constructing new, technologically advanced combat vehicles.

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 for meeting service and combatant command surge requirements for modern, new, and additional equipment that can dominate the battlefield. Consolidated industrial facilities, limited workforce, and competition for common products and other materials require prioritization across the ground vehicle supply chain.

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. The Department relies on domestic producers as well as capabilities available from allied countries in Europe. Due to USG budget uncertainties, unpredictable DoD demand, and other commercial market factors, the DIB can face challenges when trying to balance diverse demands for cold-rolled plate production capacity while also informing long-term internal capital investment decisions.

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. The Army examined the facility's capacity to support simultaneous manufacture and discovered the need for additional industry-initiated investments into the facility and the workforce with the intent to address identified concerns. The Services will continue to monitor.

Opportunities for new work, modernization, and recapitalization are important to keep prime suppliers competitive. The Department's recent and ongoing competitions for the Marine Amphibious Combat Vehicle, the Joint Light Tactical Vehicle, and the Mobile Protective Firepower are examples of incremental modernization that provided much needed work to exercise design skills across the industrial base.

DoD-sponsored manufacturing innovation institutes like Lightweight Innovations for Tomorrow (LIFT) also offer industry members education and workforce development opportunities to improve manufacturing technologies for ground systems. LIFT led one project that reduced Humvee rollovers by 74% and reduced fatalities of service men and women. The project validated quality retrofit installation on the Humvee fleet, including training soldiers on the installation process.

The Ground Vehicle Working Group will continue monitoring this sector, evaluating opportunities for research into new armored protection concepts and looking for alternatives to increase competition in maintenance and modification programs for ground vehicles. For example, the ManTech program is currently funding an effort to help reduce risk for the M1 Abrams and M2 Bradley platforms by developing new and innovative circular polarizer technologies.



5.4. Munitions and Missiles

5.4.1. Sector Overview

The munitions and missiles industrial sector is comprised of “smart” bombs, tactical (cruise, air-to-air, air-to-ground, surface-to-air) missiles, missile defense, and strategic missiles. It also includes “dumb” bombs, ammunition, mortars, artillery, and tank rounds, etc. 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 and hampered 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. There are currently only two domestic suppliers for solid rocket motors used in the majority of DoD missile systems, with foreign suppliers making up the balance for a small number of systems. One of the foreign suppliers recently established a U.S. subsidiary for tactical solid rocket motors, which will increase the health of this key sub-tier supplier base.

Over the past two decades, DoD has upgraded existing systems (i.e., new seeker), but there have been no solid rocket motor improvements. Two new tactical missile programs are in 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 Precision Strike Missile. There is also one new strategic missile program, Ground-Based Strategic Deterrent, which is the LGM 30G Minute Man III (MMIII) intercontinental ballistic missile replacement. Numerous demonstration and validation programs have been funded over the past several years by the MMIII program, providing some design work to industry, particularly to the large solid rocket motor industrial base. There has also recently

been an increase in production for precision-guided munitions due to inventory shortfalls, helping to sustain and even increase demand for sub-tier suppliers.

The ammunition and munitions base is critical to the life cycle management of more than 650 programs and over 1,200 end items. 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.

5.4.2. Sector Risks and Mitigation Strategy

The munitions and missiles sector identified multiple risks and issues, including material obsolescence and lack of redundant capability, lack of visibility into sub-tier suppliers causing delays in the notification of issues, loss of design and production skill, production gaps and lack of surge capacity planning, and aging infrastructure to manufacture and test the products.

Production gaps for munitions and missiles directly reduce the U.S. capability to deliver kinetic effects against adversaries. The following case studies 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.

Voltage Control Switch

During 2017–2018, the issue with the most impact was the obsolescence of a voltage control 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 wafer 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. The Department 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 designed to last from three to five years, would only last six months. This left insufficient time to develop, test, integrate, and qualify the new switch before the old switches were depleted. In response, DoD initiated a process to manage the allocation of the switches. This work ensured

that critical munitions requirements were met by balancing the Services' requirements and priorities to industry's production capacity.

Obsolescence of Critical Chemicals Used in DoD Missiles

Two chemicals that have pervasive use in DoD missiles became obsolete. One was a curative used in almost every solid rocket motor. The U.S. source ceased production due low DoD demand levels and environmental restrictions. The only other source is a foreign supplier. INDPOL was able to convince the U.S. supplier to continue to provide this material, albeit with a different process. It also worked with government and industry stakeholders to test and qualify it in their systems.

The other was a flame retardant chemical used in insulation for almost all solid rocket motors. The chemical was already foreign sourced, with the precursor material sole sourced from China. China no longer produces the precursor material. As a result, there is no longer a supply of the chemical and a substitute needed to be found. INDPOL coordinated a government and industry working group that identified and tested substitute materials—sharing information on their efforts to enable a more cost-efficient solution. This effort should serve as a model for how DoD and industry solve obsolescence issues.

Explosives Demand at Holston Army Ammunition Plant

A government-owned, contractor-operated facility is the only domestic source for most DoD explosives, and it has insufficient capacity to meet DoD demand for a key DoD explosive. In early FY 2016, the 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 \$800 million and with an estimated completion date of 2025.

Beyond the specific cases described above, the Missiles and Munitions Working Group has developed top-level recommendations.

The Department should:

1. Coordinate and fund obsolescence planning and mitigation.
2. Seek better visibility into sub-tier suppliers and develop better mechanisms for issue notification.

3. Fund the design and prototyping of new systems to keep design skills relevant.
4. Stabilize funding that provides a consistent demand signal to industry (at least at minimum sustaining rate production), allowing them to plan and maintain capacity and capability (and to maintain some level of surge capacity), and to maintain and improve existing infrastructure.

In parallel, IBAS, DPA Title III, and the ManTech program are investing with the Services to address risks in the munitions and missiles sector through developing and scaling traditional and advanced manufacturing processes to ensure a future supply of critical chemicals. IBAS is also funding a tactical solid rocket motor prototyping effort to revitalize critical skills necessary for next-generation missiles.

Many of the working groups and IPTs that INDPOL leads are directly tied to the munitions and missiles sector, including: CEMWG, JANNAF PIB, DoD Fuze IPT, and the JMPS IPT. These groups help identify and solve IB issues from a DoD perspective versus a service or program perspective, leading to more cost effective and efficient solutions.



5.5. Nuclear Matter Warheads

5.5.1. Sector Overview

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:

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

5.5.2. Sector Risks and Mitigation Strategy

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. Risks identified in the nuclear matter warheads sector include workforce limitations, lack of trusted sources, and sole sources of materials. Additional information about these risks is provided in the cases listed below.

Skilled, Clearable Workforce

The United States 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 United States 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.

Mitigation strategies for the nuclear matter warheads sector are classified. Information about these strategies was provided in the classified annex of the EO 13806 report.



5.6. Radar and Electronic Warfare

5.6.1. Sector Overview

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. Radar achieves detection by transmitting electromagnetic waves that are reflected off objects and returned 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 (SAR), which leverages digital signal processing to integrate radar returns over time as a radar system moves. SAR is used for search and rescue, target search/acquisition/identification/tracking, and weapons engagement. SAR 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. They 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. They also 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.

5.6.2. Sector Risks and Mitigation Strategy

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 increasingly complex digitally driven environment. The case studies illustrate areas in which the United States needs to avoid becoming outmatched 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 and 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 regard 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 of 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, 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 industrial base identified over four thousand 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. For microwave tubes, DoD has only two primary 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 United States' ability to lead advancements and retain long-term support infrastructure to support defense-specific electronics and microelectronics technologies areas will continue to be stressed. However, initiatives to support dual commercial-military use of electronics, microelectronics, and materials can help reduce the risk. For example, the Manufacturing Innovation Institutes are sponsoring projects in additive manufacturing, lightweight materials, photonics, and flexible hybrid electronics that are incentivizing industry to develop dual-use technologies.

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 the 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. The ManTech program is currently funding an effort to optimize the manufacturing techniques for cost effective production of printed chaff countermeasures.

Reduced Competition and Innovation

The military faces risk of reduced competition and innovation for tactical fighter aircraft 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. The ManTech program is funding initiatives to increase the domestic manufacturing capability of gallium nitrate (GaN) foundries. There are multiple efforts underway between the Air Force and Navy to develop these capabilities.

Recent efforts have been completed in FY 2018 to address risk areas defined in the EO 13806 report for the radar and electronic warfare sectors. Two active DPA Title III efforts are improving GaN production capabilities at current manufacturers to ensure the industrial capacity can meet current DoD requirements. In addition, the IBAS group is funding projects to move toward open system architectures for electronic warfare systems. This will expand competition to lower tier suppliers by removing the barriers caused by proprietary software. IBAS projects also look to open the GaN and unmanned aircraft system (UAS) manufacturing supply base to sub-tier suppliers. The Department has moved quickly to award contracts to mitigate supply chain risks in other areas such as digital receivers/exciters, and to investigate risks in emerging areas such as directed energy weapons.



5.7. Shipbuilding

5.7.1. Sector Overview

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 (Table 3) 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 vessels.

Table 3. Shipyards Engaged in U.S. Naval Construction

PARENT COMPANY	SHIPYARD	LOCATION	TYPE OF SHIP	SHIP CLASS
General Dynamics	Bath Iron Works	Bath, ME	Surface combatant	Arleigh Burke class destroyer (DDG 51)
				Zumwalt class destroyer (DDG 1000)
	Electric Boat	Groton, CT and Quonset Point, RI	Submarine	Columbia class ballistic missile submarine (SSBN 826)
				Virginia attack submarine (SSN 774)
	NASSCO	San Diego, CA	Fleet support	Expeditionary sea base (ESB 3)
			Combat logistics	Fleet replenishment oiler (T-AO 205)

PARENT COMPANY	SHIPYARD	LOCATION	TYPE OF SHIP	SHIP CLASS
Huntington Ingalls	Newport News Shipbuilding	Newport News, VA	Aircraft carrier	Ford class aircraft carrier (CVN 78)
			Submarine	Columbia class ballistic missile submarine (SSBN 826) Virginia attack submarine (SSN 774)
	Ingalls Shipbuilding	Pascagoula, MS	Surface combatant	Arleigh Burke class destroyer (DDG 51)
			Amphibious warfare	San Antonio class amphibious transport dock (LPD 17) America class amphibious assault (LHA 6)
			Cutter	National security cutter
Fincantieri	Marinette Marine	Marinette, WI	Surface combatant	Littoral combat ship (LCS)
Austal	Austal	Mobile, AL	Surface combatant	Littoral combat ship (LCS)
			Fleet support	Expeditionary fast transport (EPF 1)

5.7.2. Sector Risks and Mitigation Strategy

As a result of EO 13806, the Navy performed an analysis of the shipbuilding industrial base. The most significant risks found were a dependence on single and sole source suppliers, capacity shortfalls, a lack of competition, a lack of workforce skills, and unstable demand. The diminishing domestic commercial shipbuilding sector increases all of these risks. Additional information about these risks is provided in the cases listed below.

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 United States. 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

* 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.

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 and submarines 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 (DOL) 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 United States 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. One mechanism the Navy utilizes to engage with industry and address workforce changes is the LIFT manufacturing innovation institute. Managed through the Office of Naval Research, the institute develops manufacturing innovations to improve the shipbuilding processes. For example, processes to reduce thin-plate welding distortion for ship construction by 30% reduced cost by 13%.

The Navy addresses these risks through multiple long-term initiatives designed to manage these macro-economic challenges. The Navy partners with its shipbuilders and vendors to identify vulnerabilities and make both public and private investments to increase resiliency where appropriate. The Navy continues to engage with its shipbuilders and suppliers, as well as regional and national associations, to address workforce challenges across the industry such as training, mobility, and demand stability.

The SSBN 826 (Columbia) class ballistic missile submarine program remains the top priority for the Navy, and delivering that program without impacting other shipbuilding programs is a challenge. Advanced procurement funding is critical to the success of the program and necessary for the submarine industrial base to prepare for the largest workload increase in recent times.

Stability is also a long-term challenge, as changes in ship procurement plans impact the shipyards and lower-tier suppliers' workload. The timing of ship procurements is also critical to achieving the stable workload required to support the viability of the shipbuilding industrial base and to sustaining a skilled workforce. Advanced procurement for long lead-time material and economic order quantities as well as multi-program material purchases continue to be used to ensure stability in the industrial base.

In response to a shrinking commercial sector and a plan to ramp up Navy shipbuilding efforts, the Navy is increasing efforts to monitor the health, performance, and quality of the supply chain. Acquisition plans have been developed to minimize impacts to the industrial base in order to avoid increases in cost above inflation and to stimulate the participation of high-performance suppliers in the shipbuilding industrial base.



5.8. Soldier Systems

5.8.1. Sector Overview

Soldier systems include the diverse 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.

Most soldier systems subsectors have significant commercial overlap. The commercial market provides stabilizing peacetime revenue for existing defense contractors, as well as opportunities for new players to modify commercial gear to enter the defense market. Although access to the commercial market improves industrial base robustness, it also means that 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 defense-unique industrial capabilities. Often DoD is left to adapt to commercial market-driven changes, and only when unacceptable levels of industrial base risks arise may DoD intervene in order to sustain critical industrial capabilities.

The soldier systems sector is emerging from a long-term war sustainment effort largely focused on fulfilling immediate warfighter 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 for industry to remain viable. Peacetime industrial readiness losses are largely anticipated and have historically been recovered or replaced by alternatives upon the United States entering 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. The advanced designs and novel industrial capabilities needed to preserve U.S. warfighter tactical advantage require a skilled workforce and modernized industry.

5.8.2. Sector Risks and Mitigation Strategy

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. Evident industrial base risks in the soldier systems sector include single sources, capacity constraints, foreign dependency, market fragility, and diminishing manufacturing sources and material suppliers. The case studies below illustrate examples where the risk of permanent capability loss is enough to potentially warrant government action.

Erosion of U.S. Textile Industry

Between 1995 and 2009, the U.S. textile industry suffered a historic contraction, and Asian markets now dominate global textile supply. U.S. manufacturers are at a competitive disadvantage in workforce and raw material costs and availability. DoD is reliant on single sources and foreign sources, and competes with commercial demand for adequate production capacity.

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.

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. The Department is reliant on foreign capabilities to supply image intensifier tube core glass and gallium arsenide photocathodes. 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 supply risk is considered reduced as the number of global suppliers has increased over time, though available suppliers remain foreign.

The Department is monitoring, as an emerging risk, the proposed merger of two domestic manufacturers that provide essential U.S. military night vision components. As it does for items across the DoD supply chain, INDPOL is examining whether the merger could result in a loss of competition, create single source dependence, or constrain capacity.

As part of the planned risk management actions in the sector, DoD will evaluate joint requirements and acquisition strategies for prioritized warfighter systems shared across the military departments with an objective to create a more attractive and manageable customer demand signal. Soldier systems industry investments continue to be made from various DoD components, including the military departments, the DPA Title III program office, and the Defense-wide Manufacturing Science & Technology ManTech program office. Furthermore, strategic public-private partnerships such as Advanced Functional Fabrics of America (AFFOA) and the NextFlex institute for flexible hybrid electronics led by DoD are essential to incubate domestic capability and capacity, fill workforce skill gaps, and catalyze the transition of new technology from the lab bench to the warfighter.



5.9. Space

5.9.1. Sector Overview

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. NSS increasingly leverages the commercial space industry—both domestic and foreign—for many of the components used in spacecraft. While NSS systems leverage commercial space products when able, there are certain DoD performance requirements and capabilities that are more demanding or unique, which cannot be supported by the growing commercial space ecosystem. DoD and USG-wide studies and analyses have identified at-risk capabilities, fragile suppliers, and stress in the lower tiers of the space industrial base. This creates a need to both sustain fragile domestic sources and qualify new technologies and sources for next-generation systems, which are essential to address ever-increasing threats in the space domain.

The DoD space industrial base remains a niche market with highly specialized and capital-intensive capabilities that are not efficiently managed through individual program investments. Many systems currently in planning and development rely on established technologies, skills, and fragile sources. Individual programs are reluctant to invest in and qualify new technology and sources beyond specific program requirements, creating a need to sustain fragile domestic sources or obsolete technologies. The need remains to qualify and on-ramp essential new technologies and sources for other current and next-generation systems to address ever-increasing threats in the space domain. Figures 17 and 18 provide a tier-based taxonomy for launch services, satellites, and sensors.



TIER 4	TIER 3	TIER 2	TIER 1	PRIME
HARDWARE AND MATERIALS	COMPONENTS AND PARTS	ASSEMBLIES	SUBSYSTEMS	DESIGN AND INTEGRATION OF FINAL SYSTEM OR SERVICE
Adhesives Ceramics Coatings and paints Couplings Electrolytes Gaskets Hoses, Pipes, and Fittings Fuels Magnets Neoprene Nuts, Bolts, Fasteners, and Rivets Nylon Oxidizers Polyethylene Polystyrene Polyvinylchloride Rare Earth Materials/Minerals Rayon Resin Rubber Semiconductors/IC Transistors	Accelerometers Amplifiers Ball Screws Bellows Battery Cells Capacitors Carbonized Cloth Converters Diodes Engine Components Fairing Separation Devices Hydraulics Initiators Potentiometers Precision Ball Bearings Pyro actuators Relays Separation/Release Actuators Solid Rocket Propellant Vehicle Sensors	Guidance, Navigation, and Control <ul style="list-style-type: none"> Automatic Destruct System GPS Receivers Gyroscopes Payload Fairing <ul style="list-style-type: none"> Fairings Pyro Bolts Payload Adapter <ul style="list-style-type: none"> Control Command Interface Payload Parts Power <ul style="list-style-type: none"> Batteries Fuel Cells Propulsion <ul style="list-style-type: none"> Combustion Chambers Engine Controllers Nozzles Thrust Vector Control System Structures <ul style="list-style-type: none"> Booster Tanks Engine Mounting Structures Propellant Feed-Lines 	Guidance, Navigation, and Control Payload Fairing Payload Adapter Power Propulsion 	Launch Vehicle 

Figure 17. Space Sector Taxonomy: Launch Services




TIER 4	TIER 3	TIER 2	TIER 1	PRIME
HARDWARE AND MATERIALS	COMPONENTS AND PARTS	ASSEMBLIES	SUBSYSTEMS	DESIGN AND INTEGRATION OF FINAL SYSTEM OR SERVICE
Adhesives Ceramics Coatings and paints Couplings Electrolytes Gaskets Hoses, Pipes, and Fittings Fuels Magnets Neoprene Nuts, Bolts, Fasteners, and Rivets Nylon Oxidizers Polyethylene Polystyrene Polyvinylchloride Rare Earth Materials/Minerals Rayon Resin Rubber Semiconductors/IC Transistors	Amplifiers Ball Screws Bellows Capacitors Carbonized Cloth Composite Structures Diodes Engine Components Focal Plane Arrays Infrared Sensors Optical Encoders Precision Ball Bearings Phase Amplitude Controllers Pyro actuators Rate Sensors Relays Readout Integrated Circuits RF Parts Sensors Separation/Release Actuators Solar Cells Transistors Traveling Wave Tubes Visible Light Sensors	Altitude, Determination, and Control <ul style="list-style-type: none"> Earth Sensors Gyroscopes Reaction Wheels Star Trackers Anti-Jamming <ul style="list-style-type: none"> Beam-Forming Network Command & Data Handling <ul style="list-style-type: none"> Computers Decoders Guidance & Navigation <ul style="list-style-type: none"> GPS Receivers GPS Antennas Payload <ul style="list-style-type: none"> Atomic Clock Cryocoolers Imagers Traveling Wave Tube Amplifiers Power <ul style="list-style-type: none"> Batteries Photovoltaic Solar Arrays Propulsion <ul style="list-style-type: none"> Thrusters Telemetry, Tracking, and Command <ul style="list-style-type: none"> Band Filter, Duplexer, Antennas Thermal <ul style="list-style-type: none"> Heaters Radiators Solar Reflectors 	Satellite Payload Payload  Satellite Bus <ul style="list-style-type: none"> Altitude, Determination, and Control Anti-Jamming Command and Data Handling Guidance and Navigation Payload Power Propulsion Telemetry, Tracking, and Command Thermal 	Satellite 

Figure 18. Space Sector Taxonomy: Satellites and Sensors

5.9.2. Sector Risks and Mitigation Strategy

Primary areas of concern in the space sector include the following items: aerospace structures and fibers, radiation-hardened microelectronics, radiation test and qualification facilities, and satellite components and assemblies.

Space systems provide an emergent capability and strategic advantage to U.S. forces. Yet due to 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, economic policies of competitor nations (in the form of subsidies, domestic preference, etc.), and erratic demand are threats to the United States in the form of losing essential space capabilities and critical skills. The Department must remain vigilant about sources of vulnerability and maintain critical capabilities that are specialized for military applications.

The Space Industrial Base Capability Investment Program was established in 2013 to fund a systematic, sector-wide, interagency approach to identify, assess, and mitigate risk in the space industrial base. This effort is also intended to fund targeted investments to (1) maintain critical space industrial base capabilities, (2) develop manufacturing capability and qualify products and components for future insertion into programs of record, and (3) preserve decision trade space for DoD as it satisfies current and future requirements.

The SIBWG, formerly known as the Critical Technologies Working Group, the executing body for the Space Industrial Base Capability Investment Program, recognized that effective space industrial base risk mitigation is best shared among enterprise partners, who can effect targeted investments at the most important elements and, through a shared effort, maximize efficiency of investments. The Department continues to synergize implementation of space industrial base risk mitigation efforts. Consistent with titles 10 and 50 U.S.C., which require interagency collaboration in industrial and supply base risk assessments and mitigations, DoD has renewed the existing NSS Space Industrial Base Risk Management Program. The primary mechanisms for execution of mitigation activities include the DPA Title III, ManTech, and IBAS programs.

The SIBWG, through its planning cycle, proactively addresses risks and requirements across Service and agency programs by both re-scoping its existing efforts based on progress to date and identifying additional prioritized space industrial base needs. The SIBWG maintains critical technology lists from member agencies, which are integrated and prioritized to establish space industrial base risk mitigation projects.

The SIBWG, as an interagency working group, addresses these common requirements and challenges by leveraging technical expertise and cooperative funding to mitigate these risks in coordination with industry partners and investment. A coordinated strategy was established among the Missile Defense Agency, OUSD(A&S)/INDPOL, U.S. Air Force (through the Space and Missile Systems Center), National Reconnaissance Office, NASA, and other government agencies to subsidize and reduce duplication or other inefficiencies in the planned program executions for funding periods.

In addition to mitigations identified in the 2017 industrial capabilities report, the following capability mitigations and activities have begun in the past year:

- The Department established the Strategic Radiation-Hardened Electronics Council (SRHEC), a collaboration among DoD and other USG stakeholders, to ensure continued access to the strategic radiation-hardened electronics that are critical to the nation's security and defense. Efforts by the SRHEC include coordination with SIBWG efforts to ensure space-qualified components.
- Assessment of a medium-sized reaction wheel assembly to address a gap in production and the future small satellite needs.
- Assessment of secure/trusted processes to obtain Field Programmable Gate Arrays, given that the manufacture (but not design) takes place in foreign foundries.

Recently completed projects include:

- Liquid Rocket Engines—Additive Manufacturing. This project addressed the high cost and widening gap in workforce skill due to attrition and retirement. AM has the potential to reduce cost, reduce lead times, and significantly simplify production of complex space systems. The project focused on large liquid rocket engine assemblies and difficult-to-manufacture parts. The outcome resulted in an additively manufactured thrust chamber currently in qualification for use with NSS launch systems at significantly less cost, and shortened lead time to months instead of years.
- Germanium Substrates for Solar Cells. One of two projects stood up a domestic supplier of ultrapure germanium wafers for use in space solar cell manufacture. Until then, domestic solar cell manufacturers only had a single foreign source for germanium wafers. The existence of a domestic source had the added benefit of reducing the price of germanium wafers by half. The second benefit helped supply the medical detector industry with other wafers, to stabilize the commercial revenue stream. This ensures the domestic supplier can continue offering the germanium wafers to the space industry.

Based on the most recent prioritization of requirements, the SIBWG has identified 14 capabilities requiring expanded or new near-term mitigation efforts. Associated risk mitigation plans have been established but remain currently unfunded. Over 100 additional lower-risk capabilities are being actively monitored.

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 United States in the space sector. In addition, some foreign competitive space markets are essentially closed to American suppliers due to internal or member state buying policies.

Solar Cells

Solar cells are used on almost every satellite for power generation. Overall efficiency in converting sunlight to direct current power is important: the greater the efficiency, the smaller the panels needed. Those weight savings enable larger payloads or allow a longer overall spacecraft lifetime. In the case of small satellites, panel area is generally very limited, so high-efficiency cells can make or break a program. There is not enough space business for companies to justify R&D to improve cells without USG help. Suppliers have reached or are nearing the limits of current triple junction technology, so there is a considerable push in research for the next step (four and five junctions) to overcome those limits. For some mission types, greater radiation tolerance is needed for end-of-life performance. Given the overall decline of large satellite business that has not yet been offset with small satellite constellations, the domestic suppliers are struggling to sustain capability. At the same time, they compete with European suppliers who are aggressively marketing in the United States.

High-Power Space-Grade Traveling-Wave Tube Amplifiers

A traveling-wave tube (TWT) is an electronic device used to amplify radio frequency (RF) signals to high power, usually in an electronic assembly known as a traveling-wave tube amplifier (TWTA). The main components within a TWT are an electron gun (generates electron beam from cathode), a slow wave structure (supports the RF signal), and a collector (collects electron beam). TWTs are used in telecommunications and multimedia satellite systems, operating in various frequency bands (depending on application). TWTs are most suitable for space applications because of higher power efficiency and more thermal control than alternative technologies.

From the early 1990s to early 2000s, the domestic supplier's market share eroded from 50% to 12%, while Thales, a French company heavily subsidized by the French government, captured the Ka-band space TWT market. Internal and government R&D funding at the domestic supplier was reduced, negatively impacting competitiveness and ability to support government and commercial communication satellite programs. There was an earlier Title III project that successfully developed a K-band TWTA capable of twice the output power and bandwidth over the competition. The domestic supplier market share has increased, but continues to be low due to competition from European firms. Since the market for the larger geosynchronous equatorial orbit commercial communications satellites has significantly decreased in recent years, investment is needed to spur development of TWTAs better suited to the small satellite market.

Precision Gyroscopes

Precision gyroscopes are a critical component of the attitude determination, 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; 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—experiencing supply issues that threaten the viability of domestic product lines. The subcomponents used in integrated optics chips are increasingly manufactured overseas, and the laser diode supply base is consolidating and moving manufacturing offshore.

Space-Qualified Infrared Focal Plane Arrays

The manufacture of space infrared detectors depends on a single foreign source for high-quality substrates. The overall market is 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. A DPA Title III investment over the past few years established domestic providers and improved manufacturing capability for cadmium zinc telluride substrates. Any disruption of more than a few months could essentially shut down production of large, astronomy-grade mercury cadmium telluride infrared focal plane arrays, impacting quality and long lead items for satellites. A complementary IBAS program is in work to sustain the remaining two U.S. foundries through process improvements and to 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 associated domestic read-out integrated circuit sources for space applications due to low-volume production will force systems to foreign vendors or to domestically produced technologies with limited performance that will severely impact on-orbit lifetime. This could also result in loss of domestic read-out integrated circuit design expertise, critical to integration into the sensor chip assemblies that make up focal plane arrays utilized for missile early warning, missile defense, space surveillance, and awareness in space systems. Radiation-hardened digital capacitive transimpedance 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.

Past and ongoing Title III, ManTech, and IBAS projects are helping domestic suppliers reduce the cost of production for current and some new technologies. These technology advancements need to be coupled with consideration of policies that ensure that their products and the next-generation technologies can stay competitive with the foreign products on both performance and price.



5.10. Materials

5.10.1. Sector Overview

The assured supply of strategic materials and the resiliency of their manufacturing supply chains are vital to the national defense and economic security of the United States. Mitigating risks to strategic material supply chains is essential to our country's National Security Strategy³⁰ and NDS.³¹

While U.S. defense demand for materials may often represent a small fraction of overall demand, there are important domestic and foreign materials sectors that are essential to the U.S. military. There are also other domestic and foreign materials sectors that are heavily dependent on U.S. military demand. It is imperative that producers and supply chains of materials deemed essential to U.S. defense and civilian demand are robust, competitive, and able to meet surge requirements.

The sector includes both raw and “downstream” materials used in the production of value-added goods. The rare earth elements are good example of a complex, multi-tier critical mineral and corresponding “downstream” material supply chain. One of the most sophisticated applications of rare earth elements are neodymium iron boride (NdFeB) permanent magnets. These magnets are found in commercial applications such as hybrid drive vehicles, but also have critical defense applications such as precision-guided munitions. NdFeB magnets typically contain the “light” rare earth elements neodymium and praseodymium as well as the “heavy” rare earths of dysprosium or terbium. A generalized supply chain for NdFeB is shown in Figure 19 and illustrates the multiple tiers of the supply chain required to produce a magnet for a motor or actuator used in a commercial or defense application.

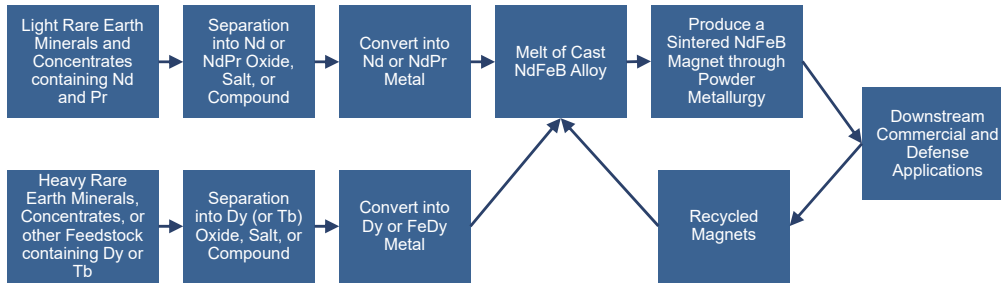


Figure 19. General rare earth element processing steps required to make a NdFeB magnet.

Other examples of strategic material supply chains tracked by DoD include high-performance aluminum and steel for ground combat vehicles and Navy ships, titanium and beryllium for military aircraft, tungsten for radars and communication systems, rare earths for guided munitions and computers, germanium for wafers and solar cells, and ceramics for body armor and microelectronics. The Department also assesses risk for highly engineered synthetic material such as high-performance carbon fibers and their composite used in missiles, aircraft, and space. In addition to innovations in newer classes of materials such as carbon nanotubes and additive manufacturing materials, innovations and other major improvements to existing materials and their processing are also significant.³²

5.10.2. Sector Risks and Mitigation Strategy

Summarized below are three significant risk areas where DoD focused risk mitigation efforts in 2018.

Overreliance on Sole Foreign Sources for Unique Proprietary Advanced Materials

The Department is reliant on sole foreign sources for a variety of advanced materials such as carbon fibers and semiconductor materials. An example of a potential risk that DoD has been working to mitigate against is sole foreign sources of unique and proprietary carbon fibers from Japan and Europe. 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. In order to mitigate this risk, DoD has been qualifying substitute materials into defense platforms as well as working with the material suppliers to create stockpiles of these materials.

Foreign Trade Impacts on Critical U.S. Material Manufacturers

Unlawful and/or otherwise unfair foreign trade practices can injure critical U.S. materials-related manufacturers. An example of DoD risk mitigation in this area is the work being done in collaboration with other USG agencies such as the DOC. For example, DoD formally participates in investigations by the DOC into the effects of foreign imports on U.S. national security. These investigations are conducted under section 232 of the Trade Expansion Act of 1962 and recently included assessments of aluminum, steel, and uranium imports.

The following emerging actions and ongoing concerns played a significant role in DoD's priorities during 2018 and will continue to be significant priorities during future years.

- **U.S. Interagency Collaboration:** The Department has worked closely with developing the U.S. interagency risk assessments and mitigation strategy response to EO 13817, A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals. This collaboration helps to ensure a further whole-of-government response to assessing and mitigating risks to the supply of strategic materials. The report for EO 13817 is anticipated in 2019, with the follow-on risk mitigation strategies to be executed over the next several years.
- **Strategic Materials Stockpiling:** The USG maintains the National Defense Stockpile as an essential reserve of strategic materials that can supply the U.S. DIB and essential civilian requirements during a declared national emergency. The National Defense Stockpile program actively assesses potential shortfalls that could occur, acquires high-risk materials for inventory purposes, and releases materials to domestic industries when needed during an emergency. The National Defense Stockpile program also actively works with industry and interagency partners (Department of Energy) in important areas of increasing materials and processing innovations (e.g., substitution and recycling) as important means of decreasing strategic and critical material supply chain risk by expanding and diversifying new sources of supply. Examples of stockpile accomplishments in 2018 include inventories of critical materials such as rare earths, antimony, carbon fibers, etc. The stockpile also continued efforts to reclaim super alloy materials from end-of-life turbine engine components and to reclaim germanium from end-of-life infrared systems.

The National Defense Stockpile plays a key role in DoD's risk strategy for strategic materials. However, there is some level of uncertainty regarding the long-term future of this program. Limited available resources within the NDS program are currently projected to result in the program reaching a financially unsustainable path by 2026. If a long-term appropriated solution is not put in place by then, sales of inventories of strategic materials, such as tungsten

and cobalt, could be forced in order to prevent program insolvency. The Department will continue to evaluate options for sustaining this program in the long term.

- **Domestic and Other Sourcing Requirements:** The USG has laws and regulations to help maintain essential domestic sources of production for critical materials and related manufactured items (e.g., armor steels, ballistic textiles, specialty metals, and aerospace alloys). These provisions require U.S. defense programs to source items only from producers located in the United States or foreign ally countries and other security partner nations. Examples include the Buy American Act, the Berry Amendment, and the Specialty Metals clause. These restrictions help ensure assured sources of supply while protecting U.S. defense programs from less reliable strategic material supply chains. The Department supports new restrictions enacted by Congress in section 871 of the John S. McCain National Defense Authorization Act for Fiscal Year 2019 (Public Law 115-232). This law prohibits DoD from procuring specific forms of tungsten and rare earth magnets from covered nations including the Peoples Republic of China (China), the Russian Federation (Russia), the Democratic People's Republic of North Korea (North Korea), and the Islamic Republic of Iran (Iran). The Department has begun monitoring the impact of this new requirement, and will continue to work with our industry partners in the DIB in order to ensure compliance.
- **Protecting Key Domestic Materials Sector Capabilities from Foreign Acquisitions:** Working through the CFIUS, DoD actively protects critical domestic material producers from certain foreign transactions. Current examples include transactions involving domestic producers of steel, alloys, composites, and other important materials and their means of production.
- **International Industrial Base Collaboration:** The Department pursues materials sector risk mitigation opportunities by working with U.S. allies and other security partner countries to increase assured sources of supply. For these purposes, DoD utilizes important authorities and enabling mechanisms such as SOSAs, Reciprocal Defense Procurement Memorandum of Understanding agreements, and international supply chain collaboration through the NTIB. The Department will continue dialogue and develop strategies to mitigate material supply chain risk through collaboration with our allies.



5.11. Cybersecurity for Manufacturing

5.11.1. Sector Overview

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. Successful operation of the defense manufacturing supply chain depends on the vast number of touch points where information flows through a network—both within and across the many manufacturers' systems that constitute the supply chain. Each of these supply chain touch points represents a potential vulnerability to the security of our nation's defense production.

5.11.2. Sector Risks and Mitigation Strategy

Cyber attacks on industry (via either enterprise or shop-floor systems, or both) can compromise weapon system technical and performance data, threaten end-product reliability, and degrade or shut down production machines and processes. The cybersecurity market is still evolving. While many firms offer potentially useful cybersecurity systems and services, many potential customers lack the technical expertise to make intelligent buying decisions and to successfully integrate disparate cybersecurity systems.

The case studies below illustrate the quickly developing field of cybersecurity and the multifaceted risks faced by the U.S. industrial base.

Lack of Awareness

Lack of awareness enables vulnerabilities to persist and potentially grow. Some manufacturers, especially the small firms, are largely unaware of cyber threats and their implications for business. They do not understand that cyber threats

can take on a multitude of different forms. Cyber threats do not necessarily come in the form of attacks on corporate networks. Cyber threats can also come in new forms, which include hardware- or software-centric attacks on the internet of things, on industrial control systems, and even on connected vehicles. Unfortunately, the problem does not stop there. Small firms are especially ill-prepared to deal with the ever-evolving number of cyber threats. The small firms simply lack the knowledge to effectively deal with these threats. This can be extremely dangerous for the U.S. industrial base as a whole. If compromised, vulnerabilities in small firms can provide a way for threat actors to hack into larger companies' connected systems, and even their corporate networks in the worst-case scenario. The larger companies would be unaware of the intrusion, especially if they believed that the small companies' systems could be trusted.

Lack of Cybersecurity Technical Knowledge

Lack of cybersecurity technical knowledge produces either apathy or poor investment choices—and both threaten DoD's equities. Cyber threats and countermeasures are constantly evolving. Gaining and maintaining cybersecurity insight is a never-ending job that can be time consuming and expensive for individual corporations. Ongoing cyber education and reinforcement are “must haves” for executives, managers, and supervisors. Manufacturers need trustworthy leaders to identify and prioritize threats and vulnerabilities and to identify, evaluate, choose, and integrate cybersecurity products and service offerings. A market full of knowledgeable buyers will drive needed improvements in cybersecurity products and services and remove those that are not up to the task of protecting a corporation's assets. Manufacturers also need trustworthy leadership to develop, implement, practice, and update cyber incident response plans. Having good cybersecurity procedures tools are not enough—they must be used efficiently and effectively.

Lack of Sound Risk Management Processes

Lack of sound risk management processes increases the likelihood of successful cyber attacks. Even though threat actors readily recognize firms that are under-prepared, cost pressures lead some manufacturers to actively minimize the importance of the cyber threat. Compliance regimes are undermined by reliance upon “self-attestation” from participants who may have little knowledge, rendering them compliant but not necessarily protected. Outside assistance is necessary to help small and mid-size manufacturers determine how to best prevent, manage, or mitigate the risks posed by cyber threats to themselves and to their individual supply chains.

Focus on Information Systems Rather than Manufacturing Systems

Most cybersecurity research and development focuses on information systems rather than manufacturing systems. As a result, the industrial base faces a higher likelihood of serious and exploitable vulnerabilities within its manufacturing systems, as well as a substantial reduction in the number of suppliers compliant with requirements and eligible to provide products and services to DoD. Defense market entry by new and innovative firms may likewise be deterred, threatening the long-term health of the defense manufacturing base. Small and mid-size manufacturers would need to have an external source of information that would allow them to become more knowledgeable regarding non-network threats. This would help to make the U.S. industrial base more secure against threats from state and non-state actors.

Inadequate Mechanisms and Forums for Sharing Information

Inadequate mechanisms and forums for sharing information with industry deny threat awareness to the most vulnerable firms in the supply chain. DoD information sharing efforts focus largely on “cleared contractors.” The vast majority of defense industrial production is done in unclassified spaces by small and medium size manufacturers (SMMs) who do not need, and cannot afford the overhead costs associated with, security clearances. At the very least, these firms need to have access to cybersecurity-related information. The access would need to come above the level of manufacturers in order for all manufacturers to have equal access to the cybersecurity information and training.

DoD recognizes these risk areas and works to mitigate them through a multifaceted strategy. The first facet is to maintain and expand open lines of communication with industry, other agencies, the R&D community, and academia. DoD continues to coordinate with industry associations and other government agencies to host “listening sessions” and technical workshops intended to develop ways to address all four sector risks. Key partners include the National Defense Industrial Association, MxD institute, and the DOC, including the National Institute of Standards and Technology (NIST). The Department recently created the Protecting Critical Technology Task Force to protect critical technology and prevent exfiltration of classified and controlled unclassified information.

The second facet is to stimulate the domestic cybersecurity market serving manufacturers. The Department has partnered with the MxD, formerly known as the Digital Manufacturing Design and Innovation Institute, to launch and operate the “National Center for Cybersecurity for Manufacturing.” The National Center will

serve as a testbed for the creation and adoption of new cybersecurity technologies to secure manufacturing shop floors across the United States. The Center will test cybersecurity use cases in a real-world manufacturing environment, develop hands-on cybersecurity training programs, and create online learning modules to reach manufacturers outside the region.

The third facet is that DoD will work closely with the Department of Homeland Security's new Cybersecurity and Infrastructure Security Agency (CISA) and the National Risk Management Center (NRMC) to improve information sharing. The CISA and the NRMC work in close coordination with the private sector and other key stakeholders in the critical infrastructure community to identify, analyze, prioritize, and manage the most strategic risks to our national critical functions. The Department will work to ensure these efforts address DoD equities throughout the supply chain.

The fourth facet is that ManTech funded the NIST Hollings Manufacturing Extension Partnership (MEP) to assess the need for and provide access to cybersecurity education, assessment, training, and online resources to SMMs. The MEP would also be able to counter the current cybersecurity trends that focus solely on information systems, by emphasizing other methods of attack such as industrial control systems.

The fifth facet relates to efforts of the Defense Security Service (DSS):

1. DSS will work closely with industry to offer qualified manufacturers access to cybersecurity training through the Center for Development of Security Excellence (CDSE). CDSE is a directorate within DSS that provides security education, training, and certification products to military personnel, civilian employees, and contractors supporting the protection of national security and professionalization of DoD security forces. DSS, as part of its security oversight of cleared contractors in the National Industrial Security Program, is increasing security oversight of Controlled Unclassified Information (CUI) related to DoD classified contracts. In this role, DSS supports and enables providing security-related threat and vulnerability information and case studies to small and mid-size manufacturers that they might not otherwise be able to access.
2. Operationally, this will expand to security oversight and counterintelligence support of CUI at cleared defense contractors that hold or process CUI related to classified contracts. Beyond its oversight of cleared contractors in the NISP, DSS is establishing enterprise capabilities to share threat information and provide guidance on implementation enabling contractors' protection of CUI across the DIB.



5.12. Electronics

5.12.1. Sector Overview

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 DoD weapon systems, but global military production represents only 6% of a market dominated by commercial devices.³³ While significant compared to overall worldwide military spending, total U.S. military spending on electronic systems is small compared to the overall A&D marketplace, as well as the commercial market. This gives 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.³⁴ This high level of investment drives 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.³⁵ Below the prime contractor level, electronics is a global industry with a supply chain spanning multiple countries and regions. This creates a high degree of interdependence among suppliers and profound implications for DoD.

5.12.2. Sector Risks and Mitigation Strategy

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 2015.³⁶ This growth has mainly been driven by China, which now captures 50% of the global market share. The U.S. share has been reduced from 25% in 1998 to less than 5% in 2015.³⁷

Microelectronic integrated circuits are the most technologically advanced level of the electronics supply chain. The global market for semiconductors has increased from \$132 billion in 1996 to \$339 billion in 2016, with the Asia Pacific market outside of Japan accounting for the vast majority of this growth—it 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. Asia accounts 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 a 51% share, marking a drop from 56% in 2015.³⁸ Maintaining access to the Chinese market is a critical concern for U.S. semiconductor companies.

The United States 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.* Increasingly, fabless companies are investing in design capabilities and services offshore. However, DoD invests in domestic trusted foundry capabilities to serve critical defense needs. It also works with interagency partners to develop the Microelectronics Innovation for National Security and Economic Competitiveness strategy. The strategy addresses current and future microelectronics needs, threats to assured access to a robust industrial base, and continued U.S. leadership.

Gaps in the electronics sector reduce the ability to 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. The Department is committed to working with industry to resolve these industrial base issues.

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 limited commercial applications and are

* A “foundry” is a semiconductor manufacturing facility that manufactures third-party designs.

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. It also works 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, with over half of that occurring 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 United States. While commercial technology advances are frequently developed in the United States, 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 becomes a risk driver for access and availability.

The Electronics Working Group is actively monitoring the risks and issues facing the defense electronics base and provides subject matter expertise and mitigation options to stakeholder investment programs such as DPA Title III, ManTech, and IBAS.



5.13. Machine Tools

5.13.1. Sector Overview

A machine tool is a power-driven machine used to shape or form parts made of metal or other materials (i.e., plastics, composites) through processes that include turning, grinding, milling, stamping, drilling, forming, extrusion, injection molding, composite deposition, and various additive manufacturing techniques. 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. 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. Modern machine tools support both prototyping and production operations. Their impact is felt across entire supply chains and industrial base sectors including transportation, aerospace, electronics, energy generation and distribution, and other critical infrastructure sectors. The global machine tool sector is very mature, and features fierce competition on price, features, and quality.

5.13.2. Sector Risks and Mitigation Strategy

U.S. machine tool production has dropped from first to sixth in the world. Key causes include the combination of Americans' loss of focus on manufacturing as a career (the move toward a service-based economy), the priorities and predatory actions of other countries, and price inelasticity, which have produced market consolidation led primarily by non-U.S. conglomerates. U.S. machine tool makers have largely exited the market. In many cases, DoD is critically reliant upon foreign machine tools makers, who often have a one- to three-year procurement lag.

The case studies below illustrate the long-term threat that the weakening of the machine tools sector, the growing dependence on foreign-produced machine tools, and increasing digitization present to the U.S. industrial base.

Lack of a Healthy U.S. Machine Tools Workforce

Lack of a healthy U.S. machine tools sector has contributed to the persistent and growing workforce shortfalls, threatening domestic design and production capability. The current machine tools workforce is in a state of steady decline. The current workforce is aging and starting to retire in larger numbers. The “pipeline” that formerly educated, prepared, and trained new skilled technicians for manufacturers is fragmented. Despite industry’s need to fill thousands of available, well-paying positions in the coming years, many parents and school personnel actively steer students away from careers in manufacturing, industrial engineering, and relevant trades (welding, machining, metalworking, etc.). There is a persistent belief that other careers provide better opportunities than manufacturing, despite recent technical advances in automation and computerization.

Increasing Foreign Dependency

Less domestic manufacturing leads to increasing foreign dependency and continues erosion of U.S. competencies. Understanding the technical details of “making processes” is critical to understanding how to create new, more capable machine tools and production machines. While education and training are important, they can never truly replace on-the-job experience. Diminishing ability to manufacture products leads to loss of the ability to conceptualize, design, and produce more advanced machine tools, production machines, and end products. That kind of lost experience can only be recovered by obtaining access to experience from those countries that still have a strong machine tools sector. Even friendly countries would be reluctant to give up the kind of advantage that having a machine tools sector would give them. Hostile countries would definitely attempt to keep that kind of powerful economic advantage all to themselves.

Industrial Digitization Creates Critical Vulnerabilities

Industrial digitization using machine tools made in other nations creates critical vulnerabilities due to continuous direct monitoring and control from outside the United States. Cyber attacks on industry (via either enterprise or shop-floor systems, or both) can compromise weapon system technical

and performance data, threaten end-product reliability, and degrade or shut down production machines and processes. Many small and mid-sized manufacturers lack the technical expertise to make and implement good cybersecurity decisions, producing either apathy or poor investments—both of which threaten DoD's equities. Cyber attacks are growing in number, type, and ferocity. A clearinghouse of cybersecurity information is becoming an absolute necessity above the manufacturer level. Government security assistance is now vital to protect the national security interests in developing a strong U.S. industrial base.

The Department recognizes these risk areas and works to mitigate them through a multifaceted strategy. The first facet is to support efforts to create the new manufacturing workforce. The Department continues to engage domestic machine tool providers to inform the training curricula required to grow skilled technicians and machinists operating production machines in order to create products that meet defense-unique needs (superalloys, large machine parts, precision optics, composite laydown and machining, hybrid manufacturing, etc.).

The second facet is to catalyze the domestic machine tool industrial base for government-unique requirements. The Department partners with the Department of Energy (DOE) Oak Ridge National Lab's Manufacturing Demonstration Facility, among others, to increase domestic machine tool design and production capacity and to support programs that stimulate workforce interest.

The third facet is to maintain and expand open lines of communication with industry, other agencies, the R&D community, and academia. The Department coordinates with industry associations and other government agencies to host "listening sessions" and technical workshops intended to develop ways to address all four sector risks. Key partners include the Association for Manufacturing Technology, MForesight, the DOE, and the DOC, including the NIST.



5.14. Organic Defense Industrial Base

5.14.1. Sector Overview

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

The organic defense industrial base is an essential subset of the larger DIB. While commercial industry is the dominant component of the DIB, organic defense industrial base activities 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. 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 accompanies every military ship, plane, vehicle, and weapon. The organic industrial 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,³⁹ and almost 14,000 aircraft.⁴⁰ Of \$587.9 billion total DoD expenditures in

FY 2015,⁴¹ \$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.⁴² DoD currently operates 17 major organic (government-owned, government-operated) depot maintenance facilities and three (government-owned, contractor-operated) manufacturing arsenals.

A military and civilian workforce spread throughout the world performs DoD maintenance. DoD materiel maintenance is performed at different organizational levels. This can range 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.

5.14.2. Sector Risks and Mitigation Strategy

Twenty years of intermittent conflict and war have driven a very high operating tempo and unprecedented system usage that have 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. Materiel readiness levels and facility condition indices show the effects of overuse and lack of infrastructure funding. 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 industrial 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.

Gaps in the organic industrial 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

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

DoD is accelerating investments in its capital improvement programs and the replacement and modernization of minor property to better align with industry recapitalization standards. In addition to ongoing studies undertaken within the Department to determine the most effective and efficient application of capital investment, the Congress, through Senate Report 115-125, asked the Government Accountability Office (GAO) to examine investments and performance of Military Service depots. The Senate Report directs each of the Military Service Secretaries to submit individual engineering master plans for the optimal placement and consolidation of facilities and major equipment to support depot-level repair functions of its government-owned and government-operated facilities and an investment strategy to address the facilities, major equipment, and infrastructure requirements at organic facilities under the jurisdiction of the respective Service. These reports are in process—for example, the Army has submitted the first of two reports on a master plan for organic industrial base infrastructure. The Department’s Logistics Reform Team has developed a series of common performance metrics that, when finalized and applied, will quickly identify threats to successfully meeting facility-related cost and schedule metrics.

Maintenance

DoD operates 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.

Most organic industrial base depots are working capital funded activities [this is not the case for Navy shipyards, which are direct mission funded] and required to reinvest and recapitalize equipment and facilities through their rate structure. Sensitivity to rate increases that are passed downstream into Service O&M budgets constrains each depot’s ability to modernize and restore infrastructure to the extent required to preserve effectiveness and improve efficiency. While DoD’s budget replaces and refurbishes plant equipment, and statute and policy direct follow-through on recapitalization, infrastructure investments have not been adequate to keep pace with commercial best practices and modern repair technologies. Without significant future investment, the organic industrial base will remain challenged by outdated equipment, tooling, and machinery. The erosion of organic infrastructure continues to impact turnaround time and repair costs of both legacy and 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 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.C. 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.

In addition to the activities mentioned above, several ongoing and interrelated mitigation strategies and initiatives are underway within DoD to address critical needs within the Department's organic industrial base. These efforts will help ensure the organic industrial base provides legislatively directed repair capabilities as well as continuity of operational readiness to meet unanticipated surge requirements.

For example, the Office of the Deputy Assistant Secretary of Defense for Materiel Readiness (OUSD(A&S)) is leading a comprehensive review of the organic industrial base. The objective of this assessment is to provide near-term actionable recommendations to preserve and posture the defense organic maintenance activities to continue providing a ready and controlled source of depot maintenance. The study will recommend improvements to the depot maintenance framework to strengthen depot maintenance linkages among the Defense Acquisition System; the Joint Capabilities Integration and Development System; Planning, Programming, Budgeting, and Execution processes; the NDS and National Military Strategy; statutory and regulatory constructs; improved governance; and reporting both within DoD and to congressional committees. It will address statutory and regulatory frameworks, Service policy, force structure, basing strategies, workload, workforce, capital investment, introduction of new technologies, and evolving sustainment strategies, which pose significant challenges for the organic depots in terms of technical competencies, facilities, equipment, and personnel.

DoD is also currently working with the Military Services to prepare a consolidated Departmental position in response to GAO draft report recommendations

concerning the poor conditions of facilities and equipment at military depots. Additionally, the report highlights compliance with the statutory annual requirement for a minimum 6% capital investment at covered depots and arsenals. This is directly related to the topic of facility investment and recapitalization. After the final GAO report is issued, the Military Services will be required to submit their corrective action plans for improvement in this area. The Department is also engaged with the Military Services on an organic industrial base depot performance and productivity deep dive. Through this effort, confirmation of current and development of potential new performance metrics will identify investment shortfalls related to organic industrial base risks.

One mechanism for evaluating and improving organic defense industrial base depot performance has come through DoD public-private partnerships. MxD, a manufacturing innovation institute, executed a Model Based Enterprise assessment of Rock Island Arsenal. The project provided Army leadership with a roadmap for leveraging digital manufacturing technologies that increase technical workforce productivity 40-45% and lower maintenance downtime by 30-50%.



5.15. Software Engineering

5.15.1. Sector Overview

Software is in virtually every piece of electronics in the form of 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 software for 90% of its avionics specification requirements. This has grown significantly over the last four decades—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 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-paced, 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.

5.15.2. Sector Risks and Mitigation Strategy

One of the significant challenges facing the DIB exists within the software engineering sector. 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. Challenges within this sector have evolved significantly over the last several decades as the demand for engineering professionals and DoD policy and processes for software has not kept pace with the current and future “software-ification” of the modern battlefield.

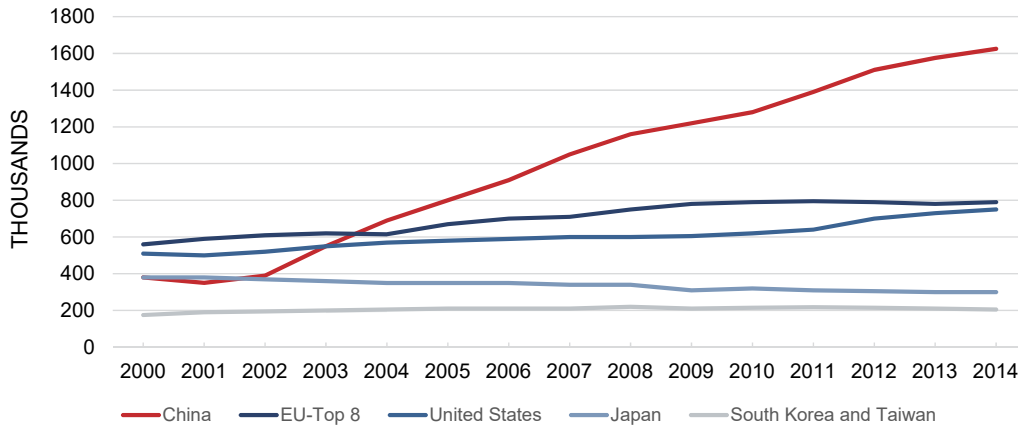
As a result of the paradigm shift from hardware- to software-intensive systems, a more software-savvy acquisition workforce is essential. Policy, roles, and responsibilities for software engineering at the DoD level are not clearly established to effectively represent software equities at the acquisition 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. There is limited visibility and understanding at the enterprise level of the total size, complexity, and characteristics of the inventory, which may exceed one billion lines 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, as resources required to meet future demands continue to grow. Over the past decade, there has been a growing chorus of concern about shortages within the STEM field.

STEM covers a diverse array of professions, from electrical engineers to researchers within the medical field, and includes a range of degree levels from bachelor’s to Ph.D. Seven out of ten STEM occupations were related to computers and information systems, with nearly 750,000 of them being software developers. Demand across all areas is not consistent. There is a surplus of Ph.D.’s seeking positions as professors in academia, while there is a shortage of electrical engineering Ph.D.’s who are U.S. citizens.⁴³

The development and sustainment of increasingly complex software-intensive weapon systems requires skills from both the engineering and computer science fields. The STEM shortage cannot be addressed solely by hiring more computer programmers. Modern software-intensive systems rely a great deal on skilled software system engineers with in-depth knowledge of the systems and environments in which the software operates (e.g., avionics systems, electronic warfare, weapons and space systems). The intersection of these disciplines creates a specialization, which results in a limited resource pool compared to the requirements of commercial application developers.

Bachelor's Degree Awards in S&E Fields,
by selected region, country, or economy: 2000–2014



Source: Indicators 2018: First University Degrees in S&E Fields, Chapter 2

Figure 20. Bachelor's Degree Awards in S&E Fields, by selected region, country, or economy: 2000–2014

It is projected that between 2014 and 2024 there will be job openings exceeding one million for computer occupations and half-a-million for engineers.⁴⁴

The STEM shortage is even more challenging for the DIB because it requires most employees to obtain security clearances, which require U.S. citizenship. Students on temporary visas in the United States have consistently earned 4%–5% of bachelor's-level STEM degrees. These students earned a substantially larger share of bachelor's degrees in industrial, electrical, and chemical engineering (11%–13%) in 2015. The number of STEM bachelor's degrees awarded to students on temporary visas increased from about 15,000 in 2000 to almost 33,000 in 2015.⁴⁵

The United States graduates fewer students with STEM degrees as a percentage of population compared to China, and the trend continues to worsen. The population of China is four times the population of the United States but produces eight times the number of STEM graduates. The United States no longer has the most STEM graduates worldwide and continues to be rapidly outpaced by China. In 2016, the United States had the third most STEM graduates worldwide with 67.4 million graduates, compared to China with 78.0 million. China continues to experience a revolution in education, with 40% of graduates in 2013 finishing with a degree in STEM.⁴⁶

The software engineering crisis in the DIB will not be corrected until significant effort is placed on updating software policy and processes, and more importantly significant investment is made in software engineering education and retention initiatives. The lack of focus on addressing the concerns in the software engineering sector will compound a significant national risk with regard to providing

the sufficient intellectual capital necessary to develop and sustain war-winning weapon systems for the modern battlefield.

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 of where software engineering and software development techniques can significantly impact, both positively and negatively, weapon system capability and readiness.

F-35 Schedule Delays and Cost Overruns Attributed To Software Development Challenges

The 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. This resulted 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. A contract was awarded to industry for this effort initially at \$54M in 2007, but it was canceled 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. By utilizing pair programming techniques coupled with continuous integration and automated testing, the

team has realized an overall improvement in time to release of 45%. In addition, defects found during acceptance testing were reduced by 88%. Leveraging the DevOps infrastructure, the team has greatly increased customer satisfaction by delivering a functional product every two weeks. This allows the users to be constantly involved and willing to embrace changing requirements, ensuring alignment with the warfighter's evolving needs.

B-1 Central Integrated Test System DevOps Implementation

In 2018, Air Force organic engineers implemented a virtual lab environment utilizing DevOps methodologies and leveraging commercial-off-the-shelf modeling and simulation software to drastically reduce the amount of time necessary to implement software changes to embedded operational flight software. The architecture of the virtual lab enables continuous integration and automated testing, allowing the developers to have a fully tested, viable product ready for formal qualification test at all times. The virtual lab allows the engineers to develop software at the same fidelity as the system integration lab without the need of physical hardware, greatly improving the efficiency of the development process while reducing the reliance on expensive aircraft hardware. Utilizing this architecture, the team has reduced the testing time from days to minutes and reduced the overall development time by up to 80%.



5.16. Workforce

5.16.1. Sector Overview

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

Around 1.6 million workers have jobs that, at least in part, support national defense.⁴⁷ This accounts for approximately 1.3% of private sector employment. The largest occupational groups within the industrial base 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.

5.16.2. Sector Risks and Mitigation Strategy

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 United States saw a sharp decline in manufacturing beginning in the 1970s, 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 2019, there were 12.8 million manufacturing jobs, up from 11.4 million in January 2010—there is still a net loss of 4.8 million jobs since 1998.⁴⁸ The skill atrophy accompanying such loss can have profound short- and long-term effects on industrial capabilities.

A National Association of Manufacturers survey of 539 manufacturing companies, conducted in December 2018, found 89% of respondents responded positively with

regard to their company's outlook. However, the same survey indicted the primary business challenges of companies to be attracting and retaining a quality workforce (68% of respondents). To address this workforce challenge, 70% of respondents said they are increasing the workload of their existing employees and 65% are creating or expanding internal training programs. The talent shortage impacts companies' ability to meet demand; 77% of respondents said they have unfilled positions they cannot fill.⁴⁹ Given the number of manufacturers who exist in the industrial base supply chain, these numbers are significant.

However, the manufacturing sector and DIB provides opportunities for employment growth. The National Association for Manufacturers reported 427,000 manufacturing job openings in January 2018, of which 360,000 were filled. This continued a strong trend in hiring since August 2017.⁵⁰ 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 conferred in the United States has increased steadily in the last two decades, the number of STEM degrees still pales compared to China.⁵¹ In addition, the United States 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.⁵²

Growth in advanced science and engineering degrees shows the United States graduating the largest number of doctorate recipients of any individual country, but 37% were earned by temporary visa holders,⁵³ with as many as 25% of STEM graduates in the United States being Chinese nationals.⁵⁴

Since the founding of the nation, STEM has been a source of inspirational discoveries and transformative technological advances, helping the United States develop the world's most competitive economy and preserving peace through strength. The pace of innovation is accelerating globally and with it, the competition for scientific and technical talent. Now more than ever, the innovation capacity of the United States—and its prosperity and security—depends on an effective and inclusive STEM education ecosystem. Individual success in the 21st century economy is also increasingly dependent on STEM literacy; simply to function as an informed consumer and citizen in a world of increasingly sophisticated technology requires the ability to use digital devices and STEM skills such as evidence-based reasoning.

The character of STEM education itself has been evolving from a set of overlapping disciplines into a more integrated and interdisciplinary approach to learning and

skill development. This new approach includes the teaching of academic concepts through real-world applications and combines formal and informal learning in schools, the community, and the workplace. It seeks to impart skills such as critical thinking and problem solving along with soft skills such as cooperation and adaptability. Basic STEM concepts are best learned at an early age—in elementary and secondary school—because they are the essential prerequisites to career technical training, to advanced college-level and graduate study, and to increasing one’s technical skills in the workplace. Increasing the overall digital literacy of Americans and enhancing the STEM workforce will necessarily involve the entire U.S. STEM enterprise.

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. Of the 15 other working groups for the EO 13806 assessment, all listed workforce in their top three risks to capacity growth and capability development. Without the required human capital, the defense industrial base will be unable to meet future needs; it is imperative the workforce challenge is addressed strategically and effectively.

To help address the manufacturing education challenges faced by the Department, the DoD ManTech program has included an education and workforce development mission in each of the eight manufacturing innovation institutes. Each institute leads education initiatives around their manufacturing technology area to increase workforce preparedness for advanced manufacturing jobs, including highly skilled technicians, skilled production workers, technical engineers, scientists, and laboratory personnel. Programs such as America Makes’ Advanced Curriculum in Additive Design, Engineering and Manufacturing Innovation (additive manufacturing), MxD’s online digital manufacturing curriculum, and AFFOA’s Advanced Fabrics Entrepreneur Program are geared towards training industry professionals. While LIFT’s Maker Minded (lightweight metals), AIM Photonic’s Future Leaders in Integrated Photonics, and NextFlex’s FlexFactor (flexible hybrid electronics) encourage and educate the next generation to pursue manufacturing jobs. Other programs such as Operation Next, created by LIFT and piloted through Fort Campbell, provide military service members with industry-driven education and skills during their transition period prior to separation.

Shortly after the Assessing and Strengthening the Manufacturing and Defense Industrial Base and Supply Chain Resiliency of the United States report was issued to the President in fulfillment of EO 13806, the Executive Office of the President issued another report titled Charting a Course for Success: America’s Strategy

for STEM Education, co-authored by members of the Departments of Education, Health and Human Services/National Institutes for Health, Energy, Commerce/ National Oceanic and Atmospheric Administration, Agriculture, Labor, and Defense; the Smithsonian Institution; and the Office of Management and Budget.

The federal government has a key role to play in furthering STEM education by working in partnership with stakeholders at all levels and seeking to remove barriers to participation in STEM careers, especially for women and other underrepresented groups. Accordingly, *Charting a Course for Success: America's Strategy for STEM Education* sets out a federal strategy for the next five years based on a vision for a future where all Americans will have lifelong access to high-quality STEM education and the United States will be the global leader in STEM literacy, innovation, and employment. It represents an urgent call to action for a nationwide collaboration with learners, families, educators, communities, and employers—a “North Star” for the STEM community as it collectively charts a course for the nation's success.

This vision will be achieved by pursuing three aspirational goals:

- Build strong foundations for STEM literacy by ensuring that every American has the opportunity to master basic STEM concepts, including computational thinking, and to become digitally literate. A STEM-literate public will be better equipped to handle rapid technological change and will be better prepared to participate in civil society.
- Increase diversity, equity, and inclusion in STEM and provide all Americans with lifelong access to high-quality STEM education, especially those historically underserved and underrepresented in STEM fields and employment. The full benefits of the nation's STEM enterprise will not be realized until this goal is achieved.
- Prepare the STEM workforce for the future—both college-educated STEM practitioners and those working in skilled trades which do not require a four-year degree—by creating learning experiences that encourage and prepare learners to pursue STEM careers. A diverse talent pool of STEM-literate Americans prepared for the jobs of the future is essential to maintaining the national security innovation base that supports key sectors of the economy, and to making the scientific discoveries and creating the technologies of the future.

The federal strategy is built on four pathways representing a cross-cutting set of approaches, each with a specific set of objectives and priority federal actions for achieving the goals outlined above:

- **Develop and Enrich Strategic Partnerships.** This pathway focuses on strengthening existing relationships and developing new connections between educational institutions, employers, and the communities. That means

bringing together schools, colleges and universities, libraries, museums, and other community resources to build STEM ecosystems that broaden and enrich each learner's educational and career journey. It also means engaging learners in work-based learning experiences with local employers, internships, apprenticeships, and research experiences. Having strategic partnerships creates opportunities within the education community to blend formal and informal learning, and to blend curricula to enable students to complete both core academic and applied technical curricula in preparation for higher education. Together, the objectives under this pathway can help retain learners interested in STEM fields and develop high-quality talent for both public and private sector employers.

- **Engage Students where Disciplines Converge.** This pathway seeks to make STEM learning more meaningful and inspiring to students by focusing on complex real-world problems and challenges that require initiative and creativity. It promotes innovation and entrepreneurship by engaging learners in transdisciplinary activities such as project-based learning, science fairs, robotic clubs, invention challenges, or gaming workshops that require participants to identify and solve problems using knowledge and methods from across disciplines. It seeks to help students challenged in mathematics—frequently a barrier to STEM careers—by using innovative, tailored instructional methods. Another objective is teaching learners to tackle problems using multiple disciplines—for example, learning data science by combining basic mathematics, statistics, and computer science to study a societal problem. Such activities help to create a STEM-literate population and prepare Americans for the rapidly evolving workplace.
- **Build Computational Literacy.** This pathway recognizes how digital devices and the Internet have transformed society and adopts strategies that empower learners to take maximum advantage of this change. It recognizes that digital literacy empowers people with the tools to find information, answer questions, and share ideas, and that they need to understand how to use these tools responsibly and safely. This pathway seeks to advance computational thinking as a critical skill for today's world. Computational thinking, including computer science, is not just about using computing devices effectively; more broadly, it means solving complex problems with data, a skill that can be learned at an early age. It seeks to expand the use of digital platforms for teaching and learning, because they enable anywhere/anytime learning; makes possible individualized instruction customized to the way each person learns most effectively; and can offer more active and engaging learning through simulation-based activities or virtual reality experiences. These tools have the potential to decrease achievement gaps in formal educational settings and to offer rapid reskilling or upskilling opportunities in the workplace.

- Operate with Transparency and Accountability. This pathway commits the federal government to open, evidence-based practices and decision making in STEM programs, investments, and activities. Complementary practices by other STEM stakeholders will facilitate the entire ecosystem to collectively monitor progress toward achieving the shared national goals of this strategic plan.

These four pathways have the potential to catalyze and empower educators, employers, and communities to the benefit of learners at all levels and to society as a whole, and to ensure the realization of a shared vision for American leadership in STEM literacy, innovation, and employment.

One of the challenges identified during the EO 13806 assessment was the lack of geographic mobility in the trade skills due to state-based licensing. In January 2017, DOL continued work with the states to reduce and eliminate licensure barriers, as well as supporting the need for portable, national credentials. The Department awarded a cooperative agreement to the National Conference of State Legislatures (NCSL), in partnership with the National Governors Association (NGA) and the Council of State Governments (CSG). NCSL convened a consortium of 11 states (Arkansas, Colorado, Connecticut, Delaware, Illinois, Indiana, Kentucky, Maryland, Nevada, Utah, and Wisconsin) to work together and provide a more portable set of credentials, reducing and eliminating barriers where possible.

A second round of grants provided six additional states (Kansas, New Hampshire, North Dakota, Oklahoma, Pennsylvania, and Vermont) with funding to conduct this same work on occupational licensing.

In addition, NCSL and CSG received smaller grants to support additional states (both grantees and other interested states).

As part of this effort, consortium member states are becoming familiar with occupational licensing policy in their particular state, learning about occupational licensing best practices in other states, and working to implement actions to remove barriers to labor market entry and improve portability and reciprocity. They will conduct studies and make recommendations for legislative, regulatory, and/or administrative procedure changes to ease licensing burdens. The grant partners (NCSL, CSG, and NGA) are providing technical assistance to teams from each of these states both as a consortium and on-site in the states. The grantee is also producing technical resources on occupational licensing of use for all states and posting them at www.NCSL.org/stateslicense.

To help support technical workers, there are numerous assistance resources available, including:

- A database comparing the licensing requirements of 34 occupations across all 50 states (the occupations do not require a bachelor's degree and are licensed in most states)
- A database of pending state legislation on licensing
- A current report on licensing issues and state solutions
- Four papers laying out issues and solutions for several populations that are particularly impacted by licensing requirements: (1) unemployed, dislocated and low-income workers; (2) veterans, transitioning service members, and military spouses; (3) persons with a criminal record; and (4) immigrants with work authorization and educational qualifications from outside the United States.

In addition, a separate grant was given in 2018 to the Kentucky Science and Technology Corporation (KSTC) to address Veterans Accelerated Learning for Licensed Occupations. KSTC is collaborating with the University of Louisville, Kentucky Community and Technical College System, Kentucky Department of Professional Licensing, USACares, and the CSG.

The grant was provided to develop a program to increase and expedite the attainment of state occupational licenses by transitioning service members and veterans in a wide variety of licensed occupations, specifically healthcare, protective service, licensed mechanical/construction occupations, and licensed transportation occupations.

The approach is to maximize academic credit for military education and training—and where partial credit is awarded, to develop a bridge curriculum to cover the missing credit areas without requiring veterans to repeat multiple courses. The Department plans to continue funding support in this area.

And finally, DOL has been working on the expansion of apprenticeships nationwide with federal and private sector partners to address the skills gaps in the industrial base occupations and beyond.

President Trump issued EO 13801, Expanding Apprenticeships in America, on June 15, 2017. The EO directed the Secretaries of Labor, Education, and Commerce to establish a task force to identify strategies and proposals to improve and promote apprenticeships, especially in sectors where apprenticeship is less prevalent. The EO also enabled the flexibility needed to create a new apprenticeship model that meets modern American workforce needs. The

task force made recommendations to help define this new model, the Industry-Recognized Apprenticeship Program (IRAP). The task force, comprised of 20 experienced members from various sectors, including manufacturing, met multiple times between November 2017 and May 2018. It was divided into four subcommittees: Education and Credentialing; Attracting Business to Apprenticeship; Expanding Access, Equity, and Career Awareness; and Administrative and Regulatory Strategies to Expand Apprenticeship. These subcommittees met individually to deliberate on subject matter related to their respective functional areas and each arrived at several recommendations, which the subcommittees presented to the full task force. The task force concluded when it transmitted its final recommendations for apprenticeship expansion to the President on May 10, 2018. Since that time, DOL has been working to implement the recommendations.

Apprenticeship is an industry-driven, high-quality career pathway where employers develop and prepare their future workforce and individuals can obtain paid work experience, classroom instruction, and a portable credential. There are two types of apprenticeship programs to support employer growth opportunities: the Registered Apprenticeship Program and the new IRAP. Both programs offer benefits to employers, such as the ability to recruit and develop a diverse and highly skilled workforce that helps business grow; improved productivity and profitability; and the ability to create flexible training options that ensure workers develop the skills needed in the workplace to fill the skills gap. For those seeking a career, an apprenticeship offers the opportunity to earn a paycheck while gaining valuable workplace skills and credentials in the field of their choice.

In today's workforce, three types of skills gaps have been identified: a lack of individuals with fundamental employability skills (basic math, communication skills, etc.); a lack of workers who have the specialized skills needed to fill many trade positions; and a lack of applicants with STEM skills, as discussed in detail earlier in this report. As we work to identify critical manufacturing and DIB occupations and others, understanding the cause of the skills gap is vital. This knowledge enables us to work with our many partners to expand and create apprenticeship programs to employ, train and/or retrain, educate, and credential the individuals needed to fill those critical positions.

The DOL has invested heavily in the expansion of apprenticeship, both in action and funding, since President Trump's signing of the EO, and it will continue to do so as apprenticeship is a proven pathway to closing the skills gap.

There is still much work to be done in the workforce area; not all of the issues will be solved by policy, legislative, and or investment strategies. A culture shift in the United States must occur that places as much value on trade skills as STEM,

and ensures the value of trade workers accurately and appropriately addresses their critical role in the defense industrial base. However, progress is being made and should be supported in order for the United States to get to the next phase of technology development and warfighting capability.



5.17. Executive Order 13806 Action Plan and Next Steps

A number of actions underway prior to the report's publication address challenges identified during the EO 13806 assessment, including:

- Near-term budget stability provided by passage of the Bipartisan Budget Act of 2018
- Passage of the FIRRMA, modernizing the CFIUS and enabling it to more effectively combat predatory Chinese economic practices⁵⁵
- Updates to the Conventional Arms Transfer policy⁵⁶ and UAS export policy to enhance domestic industrial base competitiveness⁵⁷
- Acquisition reforms to streamline and improve processes

In addition to ongoing activities, the EO 13806 action plan and recommendations use four different levers: policy, regulation, legislation, and investment. The complete action plan is classified, but the information below summarizes the recommendations, which are being led by the ITF and include leadership from multiple government agencies:

- Utilize the DPA Title III, DoD ManTech, and IBAS programs to expand investment in the lower tier of the industrial base and address critical bottlenecks, support fragile suppliers, and mitigate single points of failure
- Create an industrial policy framework in support of national security efforts, as outlined in the NDS, to inform current and future acquisition practices
- Diversify away from complete dependency on sources of supply in politically unstable countries who may cut off U.S. access
- Work with allies and partners on joint industrial base challenges through the NTIB and similar structures

- Modernize the organic industrial base to ensure its readiness to sustain current and future systems 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 to explore next-generation technology for future threats

The FY 2019 NDAA and the Department of Defense Appropriations Act for 2019 included a number of legislative and budget activities that support the mitigation activities outlined in the EO 13806 report. These include:

- Reauthorization of the DPA Title III program through 2025⁵⁸
- Authorization for the use of working capital funds to undertake minor military construction projects,⁵⁹ helping to ensure the continued readiness of the organic industrial base
- The authorization and appropriation of funds for the expansion of the submarine industrial base⁶⁰

The EO 13806 efforts will continue to inform DoD legislative and budget requests for FY 2020 and beyond to ensure ongoing support of strategic industrial base risk mitigation.

Upon receiving the EO 13806 report and action plan, President Trump directed National Security Advisor John Bolton to sign a cabinet memo instructing the appropriate cabinet secretaries to execute their assigned recommendations. The reconvening of the ITF in October 2018 enables the follow-on efforts led by DoD to implement the action plan and provide ongoing risk assessment in the industrial base.

The EO 13806 report constitutes a point-in-time assessment and provides a framework for ongoing industrial base risk assessment for DoD. The Department will continue to deliver updates on the action plan to the President, including status of risks and mitigation activities. In future years, this report to Congress will be the platform for communicating DIB risks and mitigation activities.



6. Critical New Technologies

6.1. Industrial Base Assessment of Critical New Technologies

The requirement for a robust industrial base extends beyond the production and support of current defense systems and the sustainment of legacy platforms. The DIB will be required to supply at scale the emerging technologies needed to maintain DoD's conventional overmatch while incorporating new innovations. As highlighted in the NDS, many technological developments will come from the commercial sector, meaning that they are also available to strategic competitors. The United States must continue to lead in developing new technology to maintain its leadership, while protecting the supply chain that supports these technologies. This protection must include domestic sourcing of raw materials, subcomponents, and skilled manufacturing. Without a robust domestic supply chain, the Department may find itself unable to access critical technology when it is most needed.

6.2. Assessments and Technologies

The Department recognizes the risks associated with the DIB, and has tasked INDPOL to work closely with the USD(R&E), TMIB. Initial efforts have focused on nine DoD technology modernization areas:

6.2.1. Hypersonics

Hypersonic weapon systems travel at speeds greater than Mach 5 (i.e., five times the speed of sound—approximately 3,800 miles/hour). Their speed makes them difficult to track or intercept, especially since they do not have high-altitude ballistic trajectories. They can also be retargeted and controlled while flying within the atmosphere. There are three primary variants of these systems currently under

development: hypersonic glide vehicles, cruise missiles powered by scramjet engines, and turbine-based combined cycle propulsion, which is a combination turbojet-scramjet engine. INDPOL is a member of the Hypersonics Leadership Team established by USD(R&E) and is providing industrial base capability analysis for this key technology area.

6.2.2. Directed-Energy Weapons

Directed-energy weapons provide the potential for transformation capabilities across DoD, particularly in the areas of force application and protection, by destroying fixed and fast-moving targets without the need for the stockpiling or resupply of missiles or ammunition. The Department has investigated three types of directed-energy weapons: high-energy lasers, high-power microwaves, and particle beams.

6.2.3. Artificial Intelligence (AI)/Machine Learning

To be intelligent, a system that is in a changing environment should have the ability to learn. If the system can learn and adapt to such changes, the system designer need not foresee and provide solutions for all possible situations. AI software can assess data from sensors to classify and understand the vehicle/missile/aircraft surroundings and then respond with corrective actions, without the need for human decision or interaction.

6.2.4. Quantum Science

Quantum systems use the quantum mechanical properties of superposition and entanglement. Superposition is the property that allows a system to be in two states at the same time (e.g., whereas a conventional (classical) computer bit has a value of either 0 or 1, a quantum computer bit can simultaneously have both values (0 and 1)). Entanglement is the property where pairs of qubits are linked so that what happens to one can instantly affect the other, even when they're physically separated. These properties will enable quantum systems to perform tasks that are impossible with current systems. Of interest to the DIB are quantum computers that can calculate problems in hours rather than years, communication systems that use unbreakable encryption, and radar systems that can detect stealth targets in clutter.

6.2.5. Microelectronics

Electronics is a key component of all modern defense programs. Microelectronic semiconductor integrated circuits are the lowest level of the electronics supply chain, and are the most critical and technologically advanced. The U.S.

semiconductor industry's strength lies in microelectronics design using the fabless semiconductor model, focusing on integrated circuits design and outsourcing fabrication to dedicated foundries. The most pressing tactical electronics issue consists of maintaining options for domestic trusted manufacture of custom DoD electronics and is the focus of the DoD Trusted Foundry Program, managed by the Defense Microelectronics Agency.

6.2.6. Fully Networked Command Control and Communications

Command, control, and communications (C3) are the key to managing the battlespace and exploiting information superiority as enablers of all other operational and support missions. Effective C3 assures situational awareness and provides the ability to control terrestrial, aerospace, and missile forces at all levels of command.

6.2.7. Space

The space sector includes satellites, launch services, ground systems, satellite components and subsystems, networks, engineering services, payloads, propulsion, and electronics. The Department must maintain critical capabilities that are specialized for military space applications, which typically require cutting-edge technology and stringent requirements but often have very low production quantities when compared with commercial products.

6.2.8. Autonomy

By eliminating the need for human interaction, vehicles/missiles/aircraft can operate more efficiently, make faster decisions, and reduce errors. Partially autonomous vehicles are unmanned, but require human interaction. Fully autonomous vehicles use sensors and artificial intelligence to make all decisions.


6.2.9. Cyber

Cyber espionage is epidemic and pervasive; even the world's smartest companies and government institutions have terabytes of intellectual property and financial assets being lost annually via the Internet. Concealed malicious actors even threaten our electrical power grids, global financial systems, air traffic control systems, telecommunications systems, healthcare systems, and nuclear power plants. The cybersecurity crisis is a fundamental failure of architecture and of implementation. Many of the networked technologies we depend upon daily have no effective security whatsoever. The architecture of the Internet and the vast majority of deployed software creates significant opportunities for malicious

exploitation. If infrastructure and software technologies were engineered, deployed, managed, and maintained properly, they would be built to withstand known and manage unknown risks, and they would be significantly more secure than current-day technologies, much like any other warfighter combat asset.

In response to section 1793 of the FY 2019 NDAA, DoD and the Director, National Intelligence will publish a report to the appropriate congressional committees on each of the nine technology modernization priorities. Each area will be broken into sub-categories and scored for multiple metrics in the categories of Technical Maturity, Workforce, Supply Chain, Technical Advantage, and Infrastructure. The report will highlight industrial base shortfalls, U.S. industry's ability to provide needed capability in a timely manner, key areas where the United States holds a technological advantage versus near-peer nations, and priority areas for industrial base incentives and funding recommendations. The report will represent the efforts of groups across DoD, including DARPA, the Services (such as the Air Force Research Laboratory), INDPOL, and invited subject matter experts.

As noted in the NDS: "The drive to develop new technologies is relentless, expanding to more actors with lower barriers of entry, and moving at accelerating speed." In the current environment, a single report will quickly become outdated and lose relevance. In order to maintain value and exercise the assessment methodology developed under section 1793, INDPOL will work with TMIB to use future-year industrial capabilities reports to provide updates on the priority modernization areas. It is expected that the list of technologies will shift as new fields are added and currently developing technologies become present defense requirements.



7. Conclusion

The defense industrial base supports the U.S. economy and military readiness, including unanticipated surge requirements. Therefore, the DIB is vital to the U.S. national security and defense strategies, and it must be robust, secure, resilient, and innovative in order to support warfighter requirements.

In FY 2018, DoD continued identifying industrial base risks and finding solutions to mitigate their impact. The Department's achievements during FY 2018 included the following:

- Delivered the EO 13806 report and action plan to the President. Nearly 300 impacts to the U.S. supply chain were identified during the assessment, and an action plan was created to mitigate the most critical risks. The FY 2018 industrial capabilities report provides an update on implementation of the action plan and the status of identified risks and appropriate mitigations.
- In FY 2018, and in support of EO 13806, the President signed Presidential Determinations authorizing the use of DPA Title III authorities to address key industrial base shortfalls in the production of metal castings for critical rotorcraft applications and trusted advanced photomasks for microelectronics. An additional seven presidential shortfall determinations have been signed as of April 2019. In addition, IBAS authorities supported the health and resiliency of the supply chain by investing in projects related to manufacturing skills, radar and directed energy, and solid rocket motors.
- The FIRRMA was passed into law as part of the FY 2019 NDAA. This legislation expands CFIUS's authority to review foreign investment into defense-critical technologies and defines factors affecting national security, including the effect of foreign investment on U.S. technological leadership, critical infrastructure, and capability of domestic industries to meet national defense requirements.
- DoD awarded 23.86% of small business eligible contracts to qualified small businesses in FY 2018. The DoD's MPP, which pairs small businesses with larger businesses, impacted major defense programs including the Standard

Missile-3 (SM-3), the F-35 aircraft, the KC-130J aircraft, the AN/APY-10 maritime/overland radar, the AN/FPS-132 upgraded early warning radar, and the P-8A Poseidon.

- INDPOL's industry international outreach efforts continued to increase in breadth and depth, fostering a collaborative dialogue between allies in support of our national security requirements. In FY 2018, OSD meetings at the Farnborough Air Show led to follow-on engagements that enhanced interoperability and collaboration with our British allies. The NTIB nations—Canada, the U.K., Australia, and the United States—developed a statement of principles and strategic construct for pilot projects against which to evaluate the NTIB construct. Outside of NTIB, INDPOL worked to expand the U.S.–Israeli and U.S.–Indian defense partnerships. INDPOL's Assessments group led a number of efforts, such as the Munitions War Room, which increased U.S. and allied partner readiness in munitions.
- The Department's support of the Defense Industrial Base increased with the AT&L reorganization, which created an Undersecretary of Defense for Acquisition and Sustainment and one for Research and Engineering. The new TMIB office was established in R&E, which complements the INDPOL office within A&S. This is the new home for the Defense Manufacturing Science and Technology program, which also addresses many of the gaps identified in the EO 13806 report. This program is working to mature advanced manufacturing processes to build out the ecosystems and provides resources supporting advanced manufacturing education and workforce development in (1) additive manufacturing; (2) digital manufacturing, design, and manufacturing cybersecurity; (3) lightweight metals; (4) integrated photonics; (5) flexible hybrid microcircuits; (6) smart fibers and textiles; (7) advanced tissue biofabrication; and (8) advanced robots for manufacturing.

Appendices



Appendix A: Annual Report Requirements

Section 2504 of title 10 U.S.C. requires that the Secretary of Defense submit an annual report to the Committee on Armed Services of the Senate and the Committee on Armed Services of the House of Representatives by March 1st of each year. The report is to include:

1. A description of the Departmental guidance prepared pursuant to section 2506 of this title.
2. A description of the methods and analyses being undertaken by DoD alone or in cooperation with other federal agencies to identify and address concerns regarding technological and industrial capabilities of the national technology and industrial base.
3. A description of the assessments prepared pursuant to section 2505 of this title and other analyses used in developing the budget submission of the Department for the next fiscal year.
4. Identification of each program designed to sustain specific, essential, technological, and industrial capabilities and processes of the national technology and industrial base.

This report simultaneously satisfies the requirements pursuant to title 10 U.S.C., section 2504, which requires the Department to submit an annual report summarizing DoD industrial capabilities-related guidance, assessments, and actions, and Senate Report 112-26, which accompanied the National Defense Authorization Act for FY 2012 and requires a report containing a prioritized list of investments to be funded in the future under the authorities of DPA Title III.



Appendix B: DoD Authorities to Support the Industrial Base

The Department is responsible to assess and address the health and resiliency of the defense industrial base. DoD uses title 10 U.S.C., sections 2501, 2503, 2505, and 2506, to support industrial base assessments and risk mitigation. The Department uses the following specific authorities:

- Title 10 U.S.C., section 2372, Independent Research and Development;
- Title 10 U.S.C., section 2521, Manufacturing Technology (ManTech) program;
- Title 15 U.S.C., section 18a, Hart–Scott–Rodino Antitrust Improvements Act of 1976;
- Title 50 U.S.C., DPA Title I, Defense Priorities and Allocations System (DPAS);
- Title 50 U.S.C., DPA Title III program, Expanding Production Capability and Supply;
- Title 50 U.S.C., DPA Title VII, section 721, Committee on Foreign Investment in the United States (CFIUS); and
- Title 50 U.S.C., section 2508, Industrial Base Fund.



Appendix C: Key Industrial Capabilities Assessments Completed During FY 2018

Appendix C contains information for official use only, business confidential, and proprietary. This appendix will be provided separate from this report.



Appendix D: Title III, IBAS, and ManTech Projects

Appendix D contains information for official use only, business confidential, and proprietary. This appendix will be provided separate from this report.



Appendix E: List of Acronyms

ACRONYM	DEFINITION
A&D	aerospace and defense
A&S	Acquisition and Sustainment
AFFOA	Advanced Functional Fabrics of America
AI	artificial intelligence
AM	additive manufacturing
AT&L	Acquisition Technology and Logistics
AVIC	Aviation Industry Corporation
BI&A	Business Intelligence and Analytics
C3	command, control, and communications
CAPEX	capital expenditures
CBRND	chemical, biological, radiological, and nuclear defense
CDSE	Center for Development of Security Excellence
CEMWG	Critical Energetic Materials Working Group
CFIUS	Committee on Foreign Investment in the United States
CISA	Cybersecurity and Infrastructure Security Agency
CSG	Council of State Governments
CSGC	China South Industries Group Corporation
CY	calendar year
DARPA	Defense Advanced Research Projects Agency
DIB	defense industrial base
DOC	Department of Commerce
DoD	Department of Defense
DOE	Department of Energy
DOL	Department of Labor
DPA	Defense Production Act
DPAS	Defense Priorities and Allocations System
DSCA	Defense Security Cooperation Agency
DSS	Defense Security Service
DTTI	Defense Technology and Trade Initiative
EBITDA	earnings before interest, tax, depreciation, and amortization

ACRONYM	DEFINITION
EO	Executive Order
FDI	foreign direct investment
FIRRMA	Foreign Investment Risk Review Modernization Act
FMS	foreign military sales
FY	fiscal year
GAO	Government Accountability Office
GMI	Global Markets and Investments
GaN	gallium nitride
HSR	Hart-Scott-Rodino Act
IBAS	Industrial Base Analysis and Sustainment
INDPOL	Office of Industrial Policy
IPT	Integrated Product Team
IRAP	Industry-Recognized Apprenticeship Program
ITF	Interagency Task Force
JAMSG	Joint Additive Manufacturing Steering Group
JAMWG	Joint Additive Manufacturing Working Group
JANNAF	Joint Army–Navy–NASA–Air Force
JIBWG	Joint Industrial Base Working Group
JMPS	Joint Munitions Power Sources
KSTC	Kentucky Science and Technology Corporation
LIFT	Lightweight Innovations for Tomorrow
M&A	mergers and acquisitions
ManTech	Manufacturing Technology
MEP	Manufacturing Extension Partnership
MPP	Mentor-Protégé Program
MxD	Manufacturing times Digital
NASA	National Aeronautics and Space Administration
NCSL	National Conference of State Legislatures
NDAA	National Defense Authorization Act
NDS	National Defense Strategy
NGA	National Governors Association
NIST	National Institute of Standards and Technology
NORINCO	China North Industries Group Corporation
NRMC	National Risk Management Center
NSS	National Security Space
NTIB	national technology and industrial base
NdFeB	neodymium iron boride
O&M	operation and maintenance
OSBP	Office of Small Business Programs
OSD	Office of the Secretary of Defense
OUSD	Office of the Under Secretary of Defense
PIB	Programmatic and Industrial Base

ACRONYM	DEFINITION
R&D	research and development
R&E	research and engineering
RDT&E	research, development, testing, and evaluation
RF	radio frequency
ROW	rest of the world
S&E	science and engineering
SAM	Subcommittee for Advanced Manufacturing
SAR	synthetic aperture radar
SBA	Small Business Administration
SIBWG	Space Industrial Base Working Group
SM-3	Standard Missile-3
SMMs	small and medium-size manufacturers
SOSA	Security of Supply Arrangement
SRHEC	Strategic Radiation-Hardened Electronics Council
STEM	science, technology, engineering, and mathematics
TMIB	Technology Manufacturing Industrial Base
TWT	traveling-wave tube
TWTA	traveling-wave tube amplifier
UAS	unmanned aircraft system
U.K.	United Kingdom
U.S.	United States
U.S.C.	United States Code
USD	Under Secretary of Defense
USD(A&S)	Under Secretary of Defense for Acquisition and Sustainment
USD(AT&L)	Under Secretary of Defense for Acquisition, Technology, and Logistics
USD(R&E)	Under Secretary of Defense for Research and Engineering
USG	U.S. Government



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