REPORT TO CONGRESS

Fiscal Year 2016

Annual Industrial Capabilities

Office of the Under Secretary of Defense
for Acquisition, Technology and Logistics

Office of the Deputy Assistant Secretary of Defense
for Manufacturing and Industrial Base Policy

March 2017

Preparation of this report cost the Department of Defense (DoD) a total of approximately $81,000 for Fiscal Year 2016. This includes $2,000 in expenses and $79,000 in DoD labor.

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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; Section 852 of the National Defense Authorization Act (NDAA) for FY(Fiscal Year) 2012 (Public Law 112-81), which requires the annual industrial base report to include a description of and status on the assessments of the industrial base; and Senate Report 112-26, which accompanies Section 1253, the NDAA for FY2012, 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 FY2016 and as they existed at the close of that year. It is important to note that the status of some of the programs described herein has changed in the intervening time.

Defense Industry Outlook

The defense industrial base is comprised of a diverse and dynamic set of companies and DoD organic facilities that provide products and services, directly and indirectly, to the Department to support national security objectives. It includes companies and suppliers of all kinds, from some of the world's largest public companies to small businesses. The Department relies on an industrial base that is global, commercial, and financially-complex.

Overall, the defense industry remains viable and competitive. As the industrial base continues to diversify, DoD contractors must constantly examine and realign business activities while competing for capital in competitive markets. The good news is larger defense companies remain profitable; they are carefully managing shareholder value through equity buybacks, debt reduction, reduced capital expenditures, and reductions in the labor force. Reduced costs, more transparency, and accountability in spending can lead to greater efficiency. In addition, innovative technologies are being funded and developed outside the traditional DoD acquisitions process to create new markets. However, concerns about future budget levels, in part, impact companies' investment in defense portfolios and sometimes deter new firms from working with the Department.

"… Our margin of technological superiority is slowly eroding, and addressing this issue is one of our most important strategic tasks…"

Deputy Secretary of Defense
Bob Work

"Remarks at the Space Symposium,"
Colorado Springs, CO, April 12, 2016

The Defense Industrial Base is Profitable

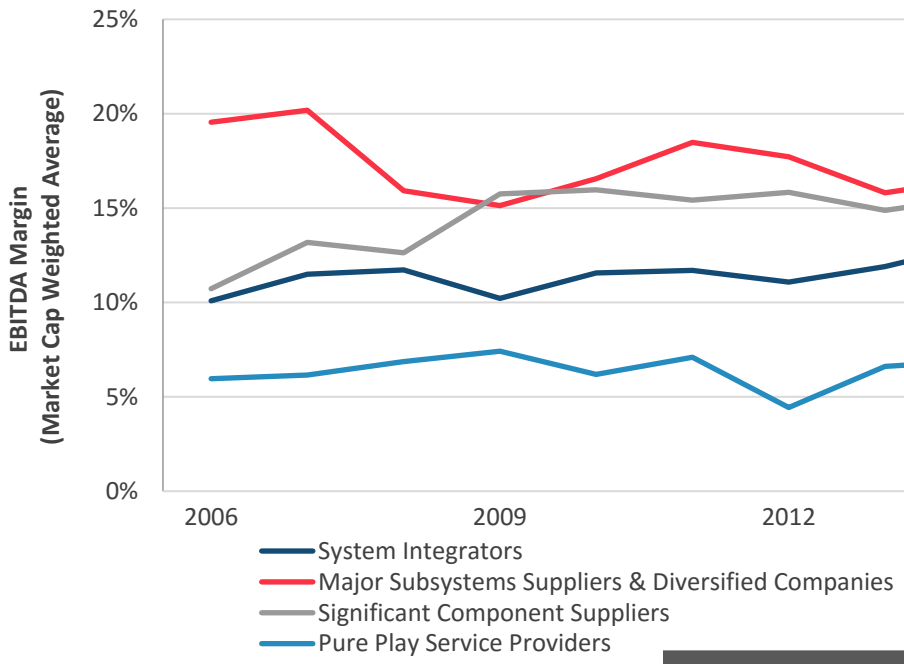
The broader Aerospace and Defense (A&D) sector has outperformed the market since 2006, with the gap widening significantly since 2012. By most financial standards and metrics, the defense industrial base is financially healthy, but there are weaknesses inside the numbers. The companies that make up the defense industrial base can be segregated into four distinct tiers: system integrators, major subsystem suppliers, significant component suppliers, and pure play service providers.

Major platform prime contractors are Lockheed Martin, Northrop Grumman, Raytheon, BAE Systems, General Dynamics, and Boeing. DoD's major subsystem suppliers such as General Electric, Rockwell Collins, and Rolls-Royce provide vital subsystems including propulsion, command and control, electronic warfare, and structural subsystems to DoD's primes. Significant component suppliers such as Kirkhill and Amphenol provide component parts including energetic and structural materials, microelectronics, cables, and connectors for prime and major subsystem providers. Pure play service suppliers such as Microsoft, CACI, Range Generation Next, and Engility Corporation provide a wide variety of services from janitorial and maintenance to advanced analyses and design engineering.

As presented in Figure 1, all tiers of the defense industrial base are profitable.[1] Earnings Before Interest Taxes Depreciation and Amortization (EBITDA) is a standard financial measure of a company's structural health. By excluding expenses such as taxes and interest, it focuses on core business expenses and revenues, and all tiers show positive margins.

[1] Weighted Average of major suppliers in each category. 6 System Integrators: $302 billion Combined Market Cap; 14 Subsystem Suppliers: $542 billion Combined Market Cap; 14 Significant Component Suppliers: $38 billion Combined Market Cap; 10 Pure Play Service Providers: $31 billion Combined Market Cap, Bloomberg.

Figure 1: EBITDA Margins by Index



Source: Bloomberg

System integrators deployed a significant proportion of its cash back to investors in the form of dividends and buybacks. This steady stream of cash has attracted investors during a prolonged low-interest environment. Most of these large systems integrators rely principally on products to maintain margins.

The major subsystems suppliers in mostly defense unique or niche markets command significant pricing power due to high barriers to entry limit new competitors. In many cases, there are few substitutes without significant cost and schedule implications resulting in low risk of competition. These suppliers are typically less diversified and can be more reliant on DoD and prime relationships. While profitable, balance sheets and smaller market size can constrict returns on investment.

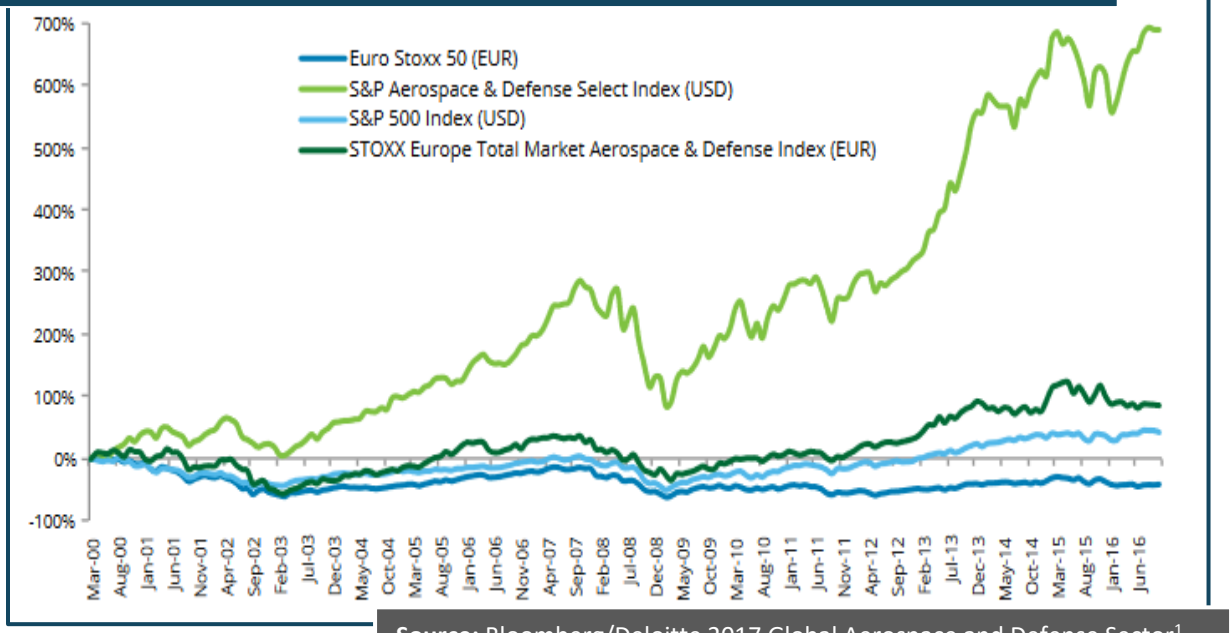
The significant component suppliers are typically the most diversified of the defense suppliers as it is easier to participate in both the defense and commercial markets, particularly in the aerospace sector. The diversity of products and components can drive inconsistent, but generally higher overall stock returns. A significant challenge for the Department is the fact that these companies, as well as lower tier suppliers principally serve in subcontractor roles limiting DoD's visibility into the supply chain.

The pure play services market is typically more competitive due to low barriers to entry, particularly given the low level of specialization and investment required for some service markets. Most pure play service providers are forced to compete on price, often eroding margins. Lower profitability generally lowers investor enthusiasm. This is a highly competitive market with an abundance of service suppliers, particularly small and medium sized "niche" firms.

On average, the broader A&D sector has significantly outperformed the overall market over a ten year period indicating market confidence in future defense industry growth as illustrated in Figure 2.

The A&D sector has been at the forefront of digital innovations, leading the way for other industries in the adoption of technologies

Figure 2: Global A&D Sector Indices Performance (2000 - 2016)



Source: Bloomberg/Deloitte 2017 Global Aerospace and Defense Sector[1]

Manufacturing Trends Impacting the U.S. Defense Industrial Base

Positive trends for the U.S. industrial base may indicate a resurgence in investment in U.S. manufacturing. According to a recent Boston Consulting Group survey, 31% of senior U.S executives reported their companies were "most likely" to add U.S. production capacity within the next five years.[3] Chinese manufacturing wages have grown an average 12% annually since 2001 which when combined with U.S. labor productivity gains, is making U.S. labor rates more competitive relative to its competitors.[4] As indicated in Figure 2 it appears the "offshoring" trend is declining and reshoring of jobs is on the rise. Of the 76% who reported likely reshoring, their primary reason was to "shorten our supply chain." The U.S. corporate income tax is by far the most uncompetitive factor cited by chief financial officers in the 2016 Insourcing Survey.[5]

[2] Deloitte, "2017 Global Aerospace and Defense Sector Outlook," https://www2.deloitte.com/content/dam/Deloitte/us/Documents/manufacturing/us-mfg-2017-global-a-and-d-sector-outlook.pdf.
[3] Nash-Hoff, Michelle, "Saving U.S. Manufacturing," *Design2Part News*, January 21, 2016.
[4] Jaxing and Yangon, "A Tightening Grip," *The Economist*, March 14, 2015.
[5] Organization for International Investment and PricewaterhouseCoopers, "CFO Insourcing Survey 2016," 2016.

Table 1: Manufacturing Jobs/Year 2015

	2000 – 2003 Annual Average	2015	% Change
New Offshoring	~240,000*	60,000*	-75%
New Reshoring & FDI* **	12,000*	67,000**	+400%
Net Jobs Gained	~220,000	~+0	N/A

***Estimated** ****Calculated**
***** Foreign Direct Investment**
Source: **Reshoring Library through December 31, 2015**[6]

Aerospace and Defense Talent Trends

U.S. student interest in the A&D market is rising

A&D companies operating in the United States have a large high-skill talent pool upon which to draw. These companies compete with other sectors of industry for the best talent. The U.S. student population interest in the A&D market is positive. In 2016, 75% of engineering students surveyed by *Aviation Week* indicated an interest in A&D careers due to the technological challenge and overall interest in the aircraft, defense, and space sectors.[7]

The Department is continuing to address talent needs through its strong support of initiatives such as the Manufacturing USA Institutes,[8] Defense Innovation Unit Experimental (DIUx),[9] and the MD5[10] National Security Technology Accelerator.[11] These initiatives provide a place for talent to gain government experience in environments similar to industry.

The Department also emphasizes strong considerations around programs to support workforce sharing in the form of fellowships and internships. The Department must continue its ongoing efforts as the need for talent across the defense industrial base is recognized by industry and government.

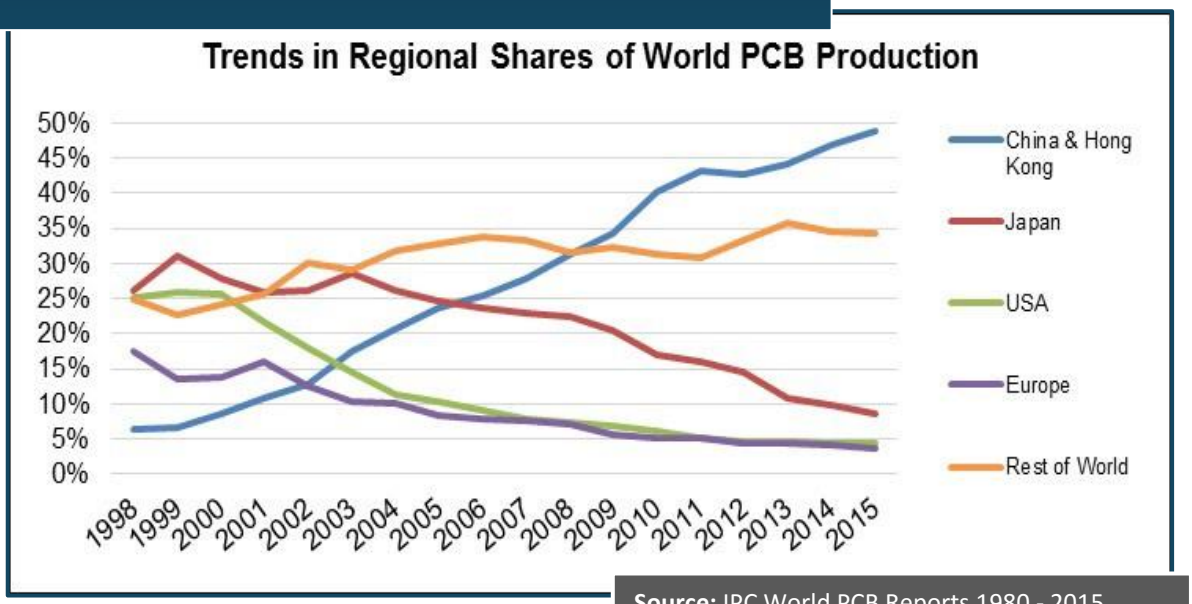
[6] Reshoring Initiative, "Reshoring, Initiative Data Report," 2015. 2016 Report not available until end of March 2017.
[7] "Aviation Week 2016 Workforce Study," *Aviation Week*, 2016.
[8] For additional information see https://www.manufacturing.gov/nnmi/.
[9] For additional information see https://www.diux.mil/.
[10] MD5 refers to Military District 5 at Fort McNair, home of National Defense University.
[11] For additional information see https://www.md5.net/about.

Foreign Direct Investment Trends

The United States continues to be an attractive option for foreign investors. Although the largest share of foreign direct investment (FDI) comes from our NATO allies and Japan, investment originating from competitor countries continues to rise and challenges our superiority in certain technology sectors. While the United States can track FDI, it is sometimes limited in its ability to review and/or mitigate national security concerns posed by this activities. In 2015, Chinese FDI in the United States outweighed U.S. FDI in China for the first time. Since 1990, China has made 1,200 U.S. acquisitions with a combined value of $64 billion, with most occurring since 2010.[12]

One area that has seen a great deal of FDI is the semiconductor market, for example. China is the world's largest market for semiconductors. They have committed to investing $104 billion over the coming decade to develop a domestic semiconductor capacity.[13] They have established goals for domestic production of semiconductors to grow from the current 4% of consumption to 40% by 2020 and 70% by 2025.[14] China has been successful in building domestic production capabilities in other industries, most notably printed circuit boards, solar panels, light emitting diode (LED) displays, and telecommunications. Figure 3 shows China's success in capturing the printed circuit board (PCB) market. Existing U.S. authorities are increasingly strained to effectively address the national security concerns caused by the changing nature of and rapid increase in FDI from China and other competitor countries.

Figure 3: China Capture of PCB Market



Source: IPC World PCB Reports 1980 - 2015

[12] "US China Ties are Deeper than You Might Think," *Bloomberg*, November 16, 2016.
[13] "China Eyes Chip Market Amid Growing Demand," *Forbes*, December 9, 2016.
[14] Center for Strategic and International Relations, "Made In China 2025," 2016.

Technological Superiority

Technology superiority is a key element of U.S. national power. Research and development investments for critical capabilities are necessary to respond to evolving threats that the United States is facing. The DoD works with industry to identify technology gaps and develop strategies that allow the United States to achieve technology superiority and affordability. Where possible, DoD relies on technology developments in the commercial market place, but defense unique capabilities may need significant investment to meet requirements. For critical defense unique products, DoD sponsors industry to support the development of technology to mitigate the risks and costs associated with a development program.

Evolving market dynamics for some defense unique products may lead to industry consolidation, restructuring considerations, or exit strategies that affect DoD's ability to respond to future warfighter needs. Robust competition incentivizes innovation and reduces cost. DoD is looking for options to reduce the impact of market changes on the industrial base. For example, DoD and industry are investing in experimental prototypes to sustain development and manufacturing teams while developing next-generation technology.

Cooperative international projects and partnerships between government, academia, and industry to co-develop and transfer technology in a way that is beneficial for all have proven to be a successful approach to promote innovation, while reducing the risks and financial burden of new development programs. These partnerships promote innovation and allow industry to combine intellectual property with DoD research labs technology and processes to get a better solution through access to new technologies, expertise, and the international industrial base.

Globalization

The defense industrial base is becoming more integrated with global commercial markets, changing both the source and tempo of innovation. As a result, the United States no longer has the luxury of assuming that it will remain the sole origin of new technology breakthroughs. Indeed, international collaboration and cooperation have reduced the time from technology breakthrough to product development available for all segments in the market, from the defense industry to corporations. Many technological advances within the defense industrial base are coming from commercialization on a global scale. This change requires that DoD acquisition processes be able to take advantage of emerging capabilities, regardless of where they originate.

Effective global supply chain integration and management are critical to DoD program success. While globalization brings many benefits to both defense firms and the Department, this cross-border collaboration has also increased the potential threat of global supply chain disruption, counterfeit parts, sabotage, and theft of critical American defense technology. This shifting landscape of defense production may require new tools and authorities to address prospective security threats and to safeguard the value and integrity of American technology.

DoD Industrial Base Priorities and Initiatives

The defense industrial base is an essential part of DoD's force structure and a pillar of the national security strategy. DoD must promote a competitive, innovative, and financially healthy industry that will provide the most affordable, highest performing capabilities to the Warfighter. It is imperative that the Department develop a more proactive and predictive approach for identifying industrial base vulnerabilities and a more comprehensive and cost-effective strategy for mitigating them. The Department moved aggressively in FY2016 to implement this vision.

Third Offset Strategy

U.S. military deterrence plans have historically been driven by offset strategies. An "offset strategy" does not try to match strength for strength, but instead seeks ways to offset competitor's advantages. A new offset strategy can become necessary when potential adversaries reach parity with the United States in a critical military area.[15]

The first offset strategy occurred in the 1950's as the Soviet Union reached parity with the United States on conventional weapons. The United States turned to tactical nuclear weapons for conventional deterrence.[16] The second offset occurred in the 70's and 80's as strategic nuclear parity was reached, and the United States turned to its focus to building an advantage in conventional guided munitions.[17] In 2016, DoD introduced plans for a "third offset" strategy, "combinations of technology, operational concepts, and organizational constructs -- different ways of organizing our forces, to maintain our ability to project combat power into any area at the time and place of our own choosing."[18] The third offset is based on the idea that the majority of important technology will come from the commercial sector, and that the technological base is global. In order to thrive in this environment, DoD must work with commercial technology to be a "fast follower," and if competitors try to copy, DoD must always be on to the next innovation.[19]

The initial third offset technology vector is to exploit advances in artificial intelligence and autonomy and insert them into DoD's battle networks to achieve a step increase in performance.[20] Other areas include assisted human operations (wearables), human-machine combat teaming (unmanned and manned equipment working together), and network enabled, cyber hardened weapons (cyber security).[21]

> …the third offset, takes systems the Defense Department already has tremendous investments in and transforms, or repurposes, them for us in ways the world has never seen, or countered."
>
> Deputy Secretary of Defense Bob Work
>
> "Remarks by Deputy Secretary Work on Third Offset Strategy," Brussels, Belgium, April 28, 2016

[15] Deputy Secretary of Defense Bob Work, "Third Offset Strategy Bolsters America's Military Deterrence" *DoD News*, October 31, 2016.
[16] Deputy Secretary of Defense Bob Work, "Remarks by Deputy Secretary Work on Third Offset Strategy," Brussels, Belgium, April 28, 2016.
[17] Ibid.
[18] Ibid.
[19] Ibid.
[20] Ibid.
[21] Katie Lange, "3rd Offset Strategy 101: What it Is, What the Tech Focuses Are", *DoDLive*, March 30, 2016.

Encouraging Innovative Entrants

One of the main priorities of the DoD is the creation of partnerships within government, industry, and academia to incentivize innovation and technological advances, develop the workforce, and collaborate to provide cost-effective products with military and commercial applications. Multiple initiatives to sustain current suppliers and to encourage the entrance of new suppliers in the defense industrial base were pursued in FY2016.

DIUx taps into the rapid evolution of commercial technology to help increase the speed and efficiency of the Department

Manufacturing USA

Manufacturing USA brings together industry, academia and federal partners within a growing network of advanced manufacturing institutes to increase U.S. manufacturing competitiveness and promote a robust and sustainable national manufacturing research and development (R&D) infrastructure. Over $600 million in federal funding has catalyzed over $1.4 billion in cost share from non-Federal sources across eight DoD-led manufacturing institutes established between 2012 and 2016 in areas ranging from additive manufacturing to robotics (for additional information see section on Manufacturing Innovation Institutes). Manufacturing USA institutes have attracted nearly 1,000 companies, universities, and non-profits across the U.S.[22]

Defense Innovation Unit Experimental

DIUx serves as a bridge between those in the U.S. military executing on some of our nation's toughest security challenges and companies operating at the cutting edge of technology. The goal of DIUx is to increase the speed and efficiency of the Department by tapping into the rapid evolution of commercial technology and to help facilitate the integration of those ideas into military systems and concepts of operation. Ultimately, DIUx creates innovative partnerships to benefit the U.S. national security community and industry. DIUx has a particular interest in engaging industry in dual-use technology areas, such as big data, analytics, autonomy, robotics, and cybersecurity.[23]

[22] For additional information see www.manufacturingusa.com.
[23] For additional information see www.diux.mil.

"We're talking about taking emerging needs and getting those requirements into the hands of our labs, our warfare centers, our engineers, our scientists and industry to start to identify what the technical solution is, what the fix is that will fill the need, so that we can cut time out of the equation."

Sean Stackley
Assistant Secretary of the Navy for Research, Development and Acquisition

"DoN Grapples With Need For Rapid Prototyping Amid Congressional Concerns" USNI News, October 7, 2016

MD5 National Security Technology Accelerator

On June 30, 2015, the National Defense University, under sponsorship from the Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics (OUSD(AT&L)), established MD5 to develop innovators (and human-centered networks) who create technology ventures relevant to national security. The Office of the Deputy Assistant Secretary of Defense for Manufacturing and Industrial Base Policy (ODASD(MIBP)) subsequently assumed sponsorship of the MD5 program.

Consistent with the DoD guidance, MD5 executes a portfolio of programs that expand innovation education opportunities and civil-military collaboration.[24,25] These programs include, but are not limited to, Adaptive Agile Leader Network (AALN), National Security Innovation Fellowships, "maker" labs, a Defense Innovation Proving Ground, and a civil-military collaboration "ecosystem."

MD5 focuses on the development of ventures (i.e., small scale technology initiatives) as a practical means to:

- Promote entrepreneurship and innovation as key elements of Joint officer and workforce development;
- Foster civil-military industrial collaboration;
- Build venture-led, dual use products that provide a sustainable competitive advantage for DoD and the defense industrial base;
- Leverage human-centered networks to develop Technology Domain Awareness; and
- Prototype and scale innovative business practices and problem-solving techniques.

[24] Secretary of Defense Memo: "The Defense Innovation Initiative," November 15, 2014.
[25] Secretary of Defense Memo: "Forces of the Future: Maintaining our Competitive Edge in Human Capital," November 18, 2015.

MD5 has successfully executed a portfolio of activities in FY2016 and early FY2017 in support of DoD human capital innovation and civil-military industry innovation objectives. Highlights include the Hacking for Defense (H4D) program, which engages high potential university students with DoD agencies to solve critical National security problems; the Marine Corps Innovation Challenge, which engages Marines in the identification and development of solutions relevant to emerging capability gaps; the AALN, which trains DoD leaders in emerging commercial innovation techniques and practices; and the MD5 Hackathon, which engages non-DoD innovators to prototype technology solutions over the course of a 48-hour collaboration event.

MIBP Activities

The ODASD(MIBP) within OUSD(AT&L) is the focal point for industrial base matters in the Department and led many DoD industrial base initiatives in FY2016.

MIBP Authorities

Section 896 of the Ike Skelton NDAA for FY 2011 (Public Law 111-383) established the ODASD(MIBP). MIBP supports the Office of the Secretary of Defense and the Service Acquisition Executives (SAE) by:

- Providing detailed analyses and in-depth understanding of the increasingly global, commercial, and financially-complex industrial supply chain essential to our national defense; and
- Recommending or taking appropriate actions to maintain the health, integrity, and technical superiority of that supply chain.

In addition to MIBP's core mission to broadly assess and address the health and resiliency of the defense industrial base (Title 10, U.S.C., Sections 2501, 2503, 2505, and 2506), it oversees important program and policy functions, including:

- Title 50, U.S.C., Section 2508, Industrial Base Fund;
- 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 10, U.S.C., Section 2521 Manufacturing Technology (ManTech) program;
- Title 50, U.S.C., DPA Title VII, Section 721, Committee on Foreign Investment in the United States (CFIUS);
- Title 15, U.S.C., Section 18a, Hart–Scott–Rodino Antitrust Improvements Act of 1976; and
- Title 10, U.S.C., Section 2372, Independent Research and Development.

This extensive and diverse portfolio enables MIBP's holistic focus on defense manufacturing, domestic and foreign business transactions, and industrial base issues.

MIBP promotes collaboration between government, educational institutions, businesses, innovators and entrepreneurs

Industrial Base Impacts in DoD Budget Deliberations and Programs

The Department continues to seek new ways to ensure that funding to mitigate risks to the industrial base is available on a priority basis. In addition to the previously discussed MD5, important FY2016 initiatives and programs led by MIBP focused on the industrial base include:

- **DPA Title III.** Title III of the DPA was established to "develop, maintain, modernize, and expand the productive capacities of domestic sources for critical components, critical technology items, and industrial resources essential for the execution of the national security strategy of the United States." Over the past six decades, this authority has been used to forge new military capabilities and push the boundaries of science and technology.

  By authorizing the use of special economic incentives, the DPA Title III program has been able to bridge gaps in domestic defense capabilities, while also steering investment in emerging technologies that have made significant transformations in military technology as well as commercial markets. Additionally, this program works closely with technical stakeholders such as the Space Industrial Base Working Group (SIBWG) to identify requirements and rectify shortcomings in the related focus area, then funding and executing appropriate projects using DPA Title III authorities and processes. Once directed by the DPA Title III program office, Air Force Research Laboratory (AFRL) and other contracting agents facilitate the project execution. DPA Title III is focused on addressing industrial resource and critical technology shortfalls facing the United States, and by statute, requests for Title III funding are approved by the President, with the concurrence of key congressional committees.

The FY2016 Budget includes support for launching new manufacturing programs designed to accelerate innovation and reinforce American competitiveness, expanding investments in manufacturing workforce training and advanced manufacturing technologies

- **The Industrial Base Analysis and Sustainment (IBAS) program.** IBAS addresses critical capabilities shortfalls in the base, specifically capabilities that are at-risk of being lost and crossing Service/DoD agency boundaries. The goal of IBAS is not to sustain all capabilities indefinitely, but to avoid reconstitution costs when capabilities are likely to be needed in the foreseeable future. IBAS makes investments only when sustainment is more cost-effective than reconstitution and results in overall cost savings to the Department.

- **Industrial Base Deputy's Management Action Group (DMAG) meeting.** In November 2016, DoD held an industrial base-focused session of the DMAG, the Department's highest decision-making body, to educate senior leadership on key industry trends and important strategic priorities. While this occurred after the end of FY2016, it demonstrates the forward thinking of the Department for FY2017. This was the fourth consecutive year that DoD held an industrial base DMAG. DoD leaders discussed the current state of the defense industrial base to gain a better understanding of the challenges it faces today and tomorrow. The discussion focused on the profitability of and investment trends in the companies that make up the defense industry, the identification of key industrial base risk areas, and some concerning trends of adversary nations in the area of FDI.

- **Manufacturing Technology (ManTech) program.** Manufacturability enables science and technology investments to become applicable, available, and affordable capabilities for the Warfighter. The ManTech program:

    - Invests in advanced manufacturing technologies and processes;
    - Disseminates information on best manufacturing processes and manufacturing technology investment outcomes;
    - Supports sustainment and enhancement of skills and capabilities of the manufacturing workforce; and
    - Coordinates with relevant programs within the Department of Defense, other Government agencies, and private sector.

  The program is overseen by Office of the Secretary of Defense (OSD) and implemented by separate Service and Defense agency offices and OSD. The principals from each office identify and integrate requirements, conduct joint planning, and develop joint strategies for the program via the Joint Defense Manufacturing Technology Panel (JDMTP). The program supports national and economic security by strengthening the U.S. defense and non-defense industrial base with supporting manufacturing needs in vital sectors, tier, and sub-tier suppliers. The ManTech program brings affordable technologies to acquisition program managers in the form and function necessary for integration into weapons and defense systems at scalable production rates.

- **Presidential Commitment to Advanced Manufacturing and Manufacturing USA Institutes.** The Administration signaled the growing importance of advanced manufacturing to the economic and national security of the United States.

  Key examples include:

  - The 2011 President's Council of Advisors on Science and Technology (PCAST) report to the President, Ensuring American Leadership in Advanced Manufacturing;
  - The 2011 establishment of the President's Advanced Manufacturing Partnership initiative across Government, industry, and academia;
  - The 2012 State of the Union Address emphasis on manufacturing's importance to the nation;
  - The 2012 release of the National Science and Technology Council's (NSTC), National Strategic Plan for Advanced Manufacturing;
  - The formation of the Department of Commerce (DoC) hosted Advanced Manufacturing National Program Office supported by DoD and other Interagency partners;
  - The release of Capturing Domestic Competitive Advantage in Advanced Manufacturing, the final report from the Advanced Manufacturing Partnership Steering Committee created by the President;
  - The 2013 State of the Union Address announcement of the formation of three new Manufacturing Innovation Institutes, one led by Department of Energy (DoE) and two led by DoD;
  - The 2013 launch of the Advanced Manufacturing Partnership Steering Committee "2.0;"
  - The 2014 State of the Union Address announcement of four additional Manufacturing Innovation Institutes; and
  - The October 2014 PCAST report to the President, Accelerating U.S. Advanced Manufacturing;
  - The April 2016 NSTC, Advanced Manufacturing report; and
  - The December 2016 PCAST report to the President, Ensuring U.S. Leadership in Semiconductors.

Manufacturing USA Institutes serve as regional hubs to accelerate technological innovation

In addition to continued investments in promising manufacturing technology and process R&D projects with identified transition paths, MIBP's leadership supported expanded efforts for DoD led Manufacturing USA Institutes. One institute, Advanced Functional Fabrics of America (AFFOA) launched in FY2016. Technological innovation and leadership in manufacturing are essential to enable our military to maintain technological advantage, but some fragmented and frail ecosystems are at risk due to infrastructure and workforce complexities. To advance the Department's goals, advanced manufacturing ecosystems must be built to meet common commercial and defense manufacturing challenges for shared risks and shared benefits. Manufacturing USA Institutes serve as regional hubs to accelerate technological innovation into both defense and commercial applications and concurrently develop the educational competencies and production processes via a shared public-private partnership.

Developing a Proactive and Predictive Approach to the Industrial Base

MIBP is transforming DoD's approach to defense industrial base challenges. MIBP is focusing efforts on improving the understanding of and interaction with the increasingly global, commercial, and financially complex industrial base essential to our national defense.

DIBNow

Central to this initiative is the development of a business intelligence and analytics (BI&A) capability for analysis of the defense industrial base. The intent of this effort is to deliver business intelligence and analytics products to decision makers to support robust, innovative, affordable, and technologically superior defense industrial capabilities today and in the future. Taking advantage of big data principles, MIBP is leading efforts to provide effective and timely analytics on global and domestic defense industrial base trends and health.

MIBP developed an initial BI&A capability, "DIBNow," in FY2016. The initial version of the platform established a secure "data lake" of both structured and unstructured data from government, commercial, and open sources. MIBP utilized data science techniques to index, refine, and connect diverse data sources to provide new and impactful analysis of the defense industrial base. To deliver this capability, MIBP developed a secure web-based front end, allowing users of the platform to monitor and explore defense industrial base suppliers, markets, and transactions using the latest available data.

Development of the DIBNow platform will continue in FY2017. Future development efforts focus on refining existing data sources, incorporating new data feeds from government and commercial sources. MIBP will also continue to develop advanced data analysis techniques and methodologies, extracting maximum value from data sources, and providing new insight into the defense industrial base. Specific areas of focus will include: establishing a flexible taxonomy for sector and capability analysis, enhancing visibility into lower-tier defense suppliers and products, and delivering robust analysis of mergers, acquisitions, and other transactions that affect the defense industrial base. MIBP will also continue collaborative efforts with other agencies, fostering data-sharing agreements and exchanging analytic best practices to ensure a holistic view of the defense industrial base across the Department.

"We are in a period of incredible technological flux. Advances in autonomy and artificial intelligence and autonomous control systems and advanced computing and big data and learning machines and intuitive rapid visualization tools, meta-materials, miniaturization. They are leading us to a period of a time of great human-machine collaboration."

Deputy Secretary of Defense
Bob Work

"Remarks at the ACTUV "Seahunter" Christening Ceremony"
Portland, OR, April 7, 2016

Industrial Base Council

MIBP continued to raise the visibility on defense industrial base issues within DoD during 2016. While annual industrial base DMAG sessions have been held for four consecutive years, there has generally been limited visibility on industrial base issues at senior DoD levels. As a result, MIBP established the Industrial Base Council (IBC) in 2015 that provides an executive level forum for senior DoD leaders to review and discuss key defense industrial base trends and issues to:

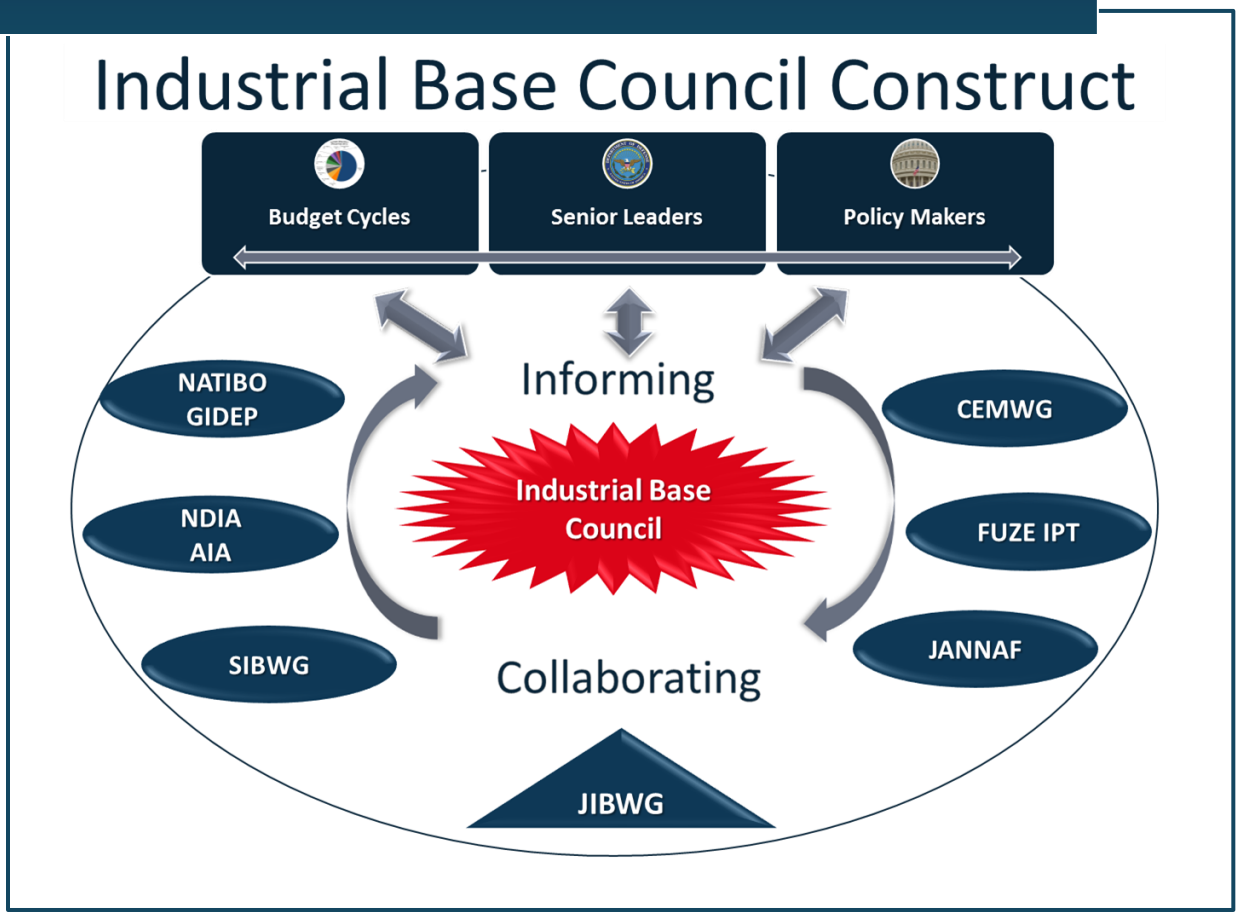
- Inform and facilitate enterprise-wide program investment decisions;
- Develop policies, programs, and business incentives to mitigate industrial base vulnerabilities and attract innovative technology suppliers; and
- Seek ways to diversify investments to attract new and innovative technology suppliers.

The IBC consists of three-star level representatives from the Military Departments, relevant agencies, and OSD organizations focused on industrial base matters. The IBC met twice in 2016 discussing global market trends, foreign direct investments, industrial base vulnerabilities, and other issues of interest. The IBC has the expectation to meet periodically in 2017 and beyond. The IBC fits within the eco-system of the DoD industrial base collaboration as illustrated in Figure 4.[26]

The IBC vision is to serve as a catalyst for informing, collaborating, and mitigating industrial base issues

[26] The DoD industrial base eco-system consists of the following working groups: the North American Technology and Industrial Base Organization (NATIBO); the Government-Industry Data Exchange Program (GIDEP); Trade associations such as the National Defense Industrial Association (NDIA) and Aerospace Industries Association (AIA); the Space Industrial Base Working Group (SIBWG); the Joint Industrial Base Working Group (JIBWG); the Joint Army Navy NASA Air Force (JANNAF); the Fuze Integrated Product Team (IPT); and the Critical Energetic Materials Working Group (CEMWG).

Figure 4: The DoD Industrial Base Eco-System



Outreach

Enabling communication with industry is critical to increasing collaboration between DoD and the private sector. MIBP plays an active role in building relationships with companies of all sizes, directly and through industry associations. Biannually, USD(AT&L) and AT&L senior leaders meet with the AIA Executive Committee, as well as leadership teams of the major prime defense companies (known as the Big 6).

Enabling communication is critical to increasing collaboration between MIBP and other agencies, Senior Leaders, Policy Makers, and Industry

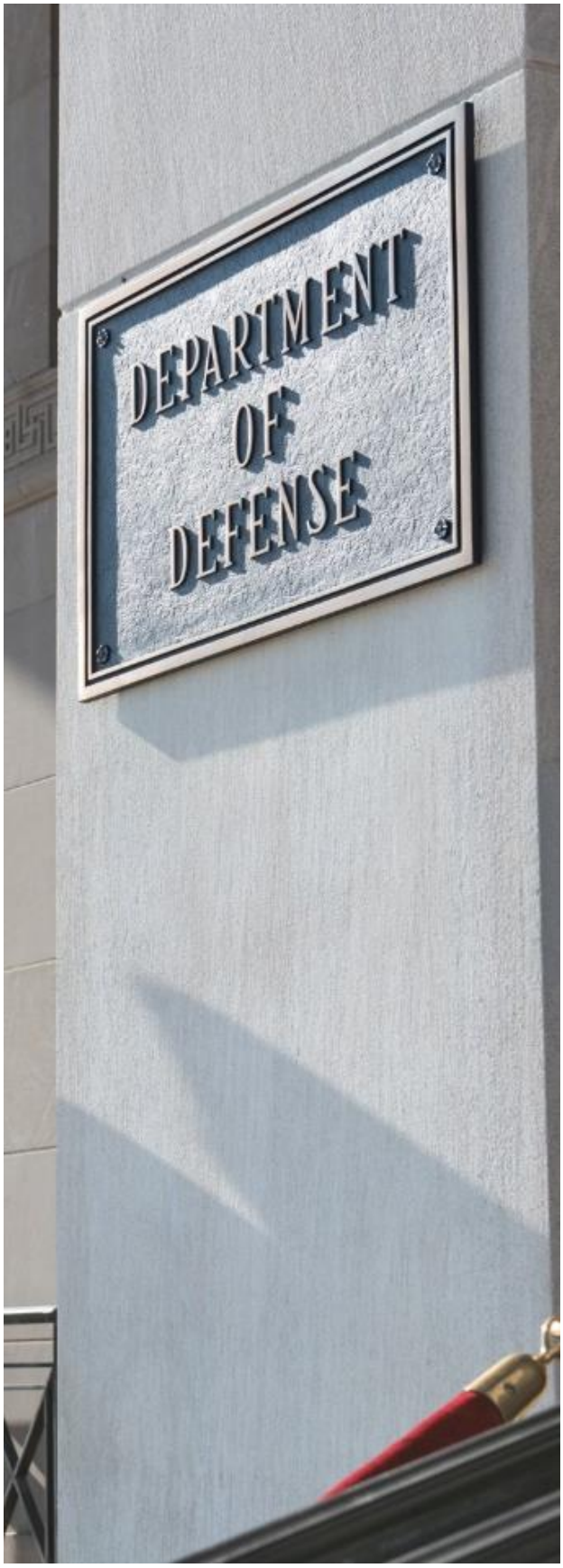
In addition to these regularly scheduled meetings, MIBP leads ongoing engagements with companies and other industry associations throughout the year. As the Department's outreach activities grew with the implementation of Better Buying Power 1.0, 2.0, and 3.0,[27] MIBP's role commensurately grew. MIBP's outreach efforts, along with programs such as DIUx, MD5 National Security Technology Accelerator, Manufacturing USA Institutes, Small Business Innovation Research/Small Business Technology Transfer, Rapid Innovation Fund, and others continue to increase the breadth and depth of industry engagement around innovation in the defense industrial base and in manufacturing, a core component of MIBP's mission and national security requirements.

Monitoring Industry Consolidations

Companies constantly adjust to market conditions and function efficiently when allowed to operate in this manner. However, free markets can also allow for industry consolidations that can unduly restrict competition and cause market distortions that can weaken the health of the industrial base. The Department must intervene in the marketplace only when necessary to maintain access to critical capabilities that might otherwise disappear or when concentration provides disproportionate pricing power to the determent of taxpayers. On occasion, for example, this may require DoD to sustain supplier capacity to ensure continuity in design and development even if no new procurements in that sector are anticipated in the short term.

MIBP plays an active role in building relationships with companies directly and through industry associations

[27] Better Buying Power 1.0, 2.0, and 3.0 focused on increasing engagement with industry to promote collaboration and innovation. For additional information see http://bbp.dau.mil/.



DoD Approach to Industrial Base Assessments

MIBP has focused its resources on ensuring that when indications of potential industrial concerns arise they are identified, analyzed, and effectively integrated into key DoD budget, acquisition, and logistics processes. DoD-wide industrial assessments evaluate and address changes and issues in key system, subsystem, component, and/or material providers that supply many programs and affect competition, innovation, and product availability.

DoD Components conduct their own assessments when there is an indication that industrial or technological capabilities associated with an industrial sector, subsector, or commodity important to a single DoD Component could be lost or to provide industrial capabilities information to help make specific programmatic decisions. These assessments generally are conducted, reviewed, and acted upon internally within the DoD Components.

Fragility and Criticality Assessment Methodology

MIBP continued the work it began in 2013 to refine a more technically rigorous methodology for identifying and mitigating weaknesses in the defense industrial base. The methodology involves subject matter experts in a sustained process of identifying and assessing the most vulnerable sectors, with breakdowns by sector tier and sub-tier. The methodology, known as the Fragility and Criticality (FaC) assessment, is intended to serve as a model for other agencies.

"Fragility" and "criticality" are roughly analogous to the traditional risk factors of probability and consequence. Fragility factors are those that make a specific product or service likely to be disrupted. Criticality factors are those that make a product or service difficult to replace. MIBP's assessment model is based on four fragility factors and six criticality factors. The four fragility factors are the total number of firms engaged in manufacturing a product or service, their current DoD sales level and broad financial outlook, and their degree of foreign dependency. The six criticality factors are the skilled labor, design, and facility/equipment requirements needed to produce a military product or service, its "defense uniqueness," the availability of alternative sources, and the time and cost required to replace it.

"FRAGILITY"

Factors likely to disrupt a specific product or service.

- ❑ DoD Sales
- ❑ Financial Outlook
- ❑ Firms in Sector
- ❑ Foreign Dependency

"CRITICALILITY"

Factors that make a product or service difficult to replace.

- ❑ Availability of Alternatives
- ❑ Defense Design Requirements
- ❑ Defense Uniqueness
- ❑ Facility/Equipment Requirements
- ❑ Reconstitution Time
- ❑ Skilled Labor

The Fragility and Criticality (FaC) assessment is intended to serve as a model for other agencies

Data Driven Assessments

Industrial base issues highlight the need for the Department to continue to improve its requirements generation process particularly for contingency operations, in order to provide better and timelier guidance to its industry partners. The Department must carefully balance the costs associated with maintaining excess production capacity for operationally-critical items in order to respond to a sudden accelerated production requirement, the unavoidable lead time necessary to fund and establish increased production capacities for those items, and the risk associated with having only a marginal peacetime production capacity on which to draw should sudden accelerated production become necessary.

Whenever DoD identifies conditions where requirements could potentially exceed the capabilities or capacities of suppliers, studies are conducted to assess the ability of suppliers to meet those requirements and to identify appropriate actions that may be needed to ensure continued availability of the full range of supplies and services.

Some examples of specific conditions which may result in the need to conduct industrial base studies include:

- Contingency requirements or operational lessons learned;
- Incremental changes or dislocations in the defense industrial base;
- DoD's annual budget development cycle;
- Studies required by Defense Authorization or Appropriation Acts and congressional letters citing specific industrial concerns; and
- Changes to defense industrial base to support transformation of Warfighter capabilities.

Defense Planning Guidance Risk Review

The Defense Planning Guidance (DPG), produced annually, includes consideration of fragile and critical industrial base issues. MIBP coordinates an annual data call to the Services and other DoD Agencies that identify DoD industrial base areas of risk. During FY2016, MIBP developed a DPG Data Input and Retrieval System to provide a collaborative tool for government agencies to collect and share industrial risk information with DoD and other government agencies. This system will help to standardize the inputs received through the DPG data call and complete a fast and customize analysis of the data considering multiple factors. The system will be used to collect the FY2017 DPG data. MIBP will continue working on the development of data analytics options during FY2017.

Industrial Sector Assessments

The following sub-sections review the results of the main MIBP assessments conducted during FY2016. Subsequent sections of this report review the results of additional assessments, including those conducted by MIBP in conjunction with other agencies.

Aircraft Sector Industrial Summary

Industry Overview

The aircraft sector is comprised of commercial and defense products. The defense aircraft industrial base is divided into three sub-sectors:

- ***Fixed Wing*** includes fighters, bombers, cargo, transportation, and any manned aircraft that uses a set of stationary wings to generate lift and fly. Large airframes and subsystems rely heavily on commercial technologies, processes, and products, and will be sustained by ongoing and planned military and commercial aerospace programs. However, defense unique design and manufacturing skills are needed to meet the requirements of military weapon systems, produce next-generation aircraft, and maintain technological advantage.

- ***Vertical Lift*** includes the helicopters used for a variety of military missions that fall into three main areas: combat, combat support, and services. Unlike commercial helicopters, DoD helicopters operate in harsh battlefield environments, which require robust, advanced capabilities and systems such as fire control, armor, weaponry, night vision, advanced avionics, stealth, speed, and power. As a result, unique design and engineering capabilities are needed to design, produce, and test DoD helicopter systems. These capabilities are not required for the commercial market.

- ***Unmanned Aircraft Systems/Vehicles (UA/UAS)*** include the necessary components, equipment, network, and personnel to control an unmanned aircraft; in some cases, UAS also include a launching element. UAs typically fall into one of six functional categories: target and decoy, reconnaissance, combat, logistics, R&D, and civil/commercial (although multi-role airframe platforms are becoming more prevalent). The growing demand for increasingly sophisticated and versatile unmanned systems reflects the Warfighter's need for intelligence, surveillance, and reconnaissance support that can reduce the risk to combat forces and associated deployment costs.

Budget Considerations

In FY2016, the procurement funding for fixed wing aircraft continued to remain steady at approximately $24 billion. Figure 5 illustrates that under current budget planning, fixed wing aircraft funding is projected to remain stable for the next 5 years.

Figure 6 illustrates that funding for vertical lift aircraft peaked in 2011 at $13.1 billion and subsequently declined as a result of reductions in overseas operations. Current funding is focused on maintaining the fleet with modernization efforts. For the next five years, the average procurement funding for vertical lift is $7.8 billion per year.

Figure 7 illustrates that funding for UA/UAS remained steady with slight declines as a result of the transition of several of UAS programs from engineering and manufacturing development (EMD) and production to sustainment and decreased production levels. The procurement investments in the UA/UAS sub-sector will stay stable, with an average of $1.0 billion per year from 2017 to 2021.

In FY2016, Research, Development, Test and Evaluation (RDT&E) funding for the aircraft sector increased by 11% compared to the previous year.

Overall procurement for aircraft appears to remain steady and stable with the exception of vertical lift aircraft while RDT&E is increasing in the near term

Figures 5, 6, and 7: Aircraft Funding Profiles

Figure 5: Fixed Wing Aircraft Procurement and RDT&E Funding Profile

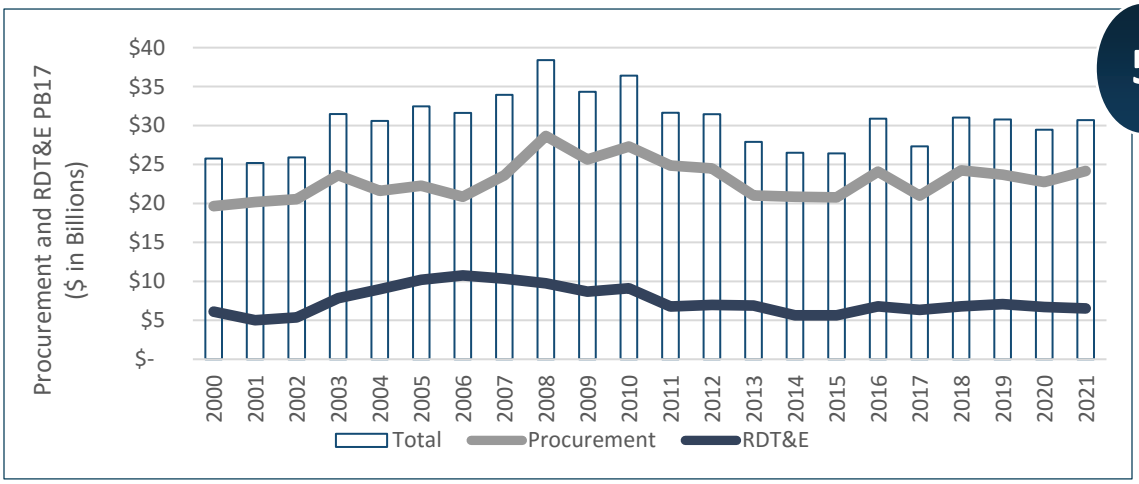


Figure 6: Vertical Lift Aircraft Procurement and RDT&E Funding Profile

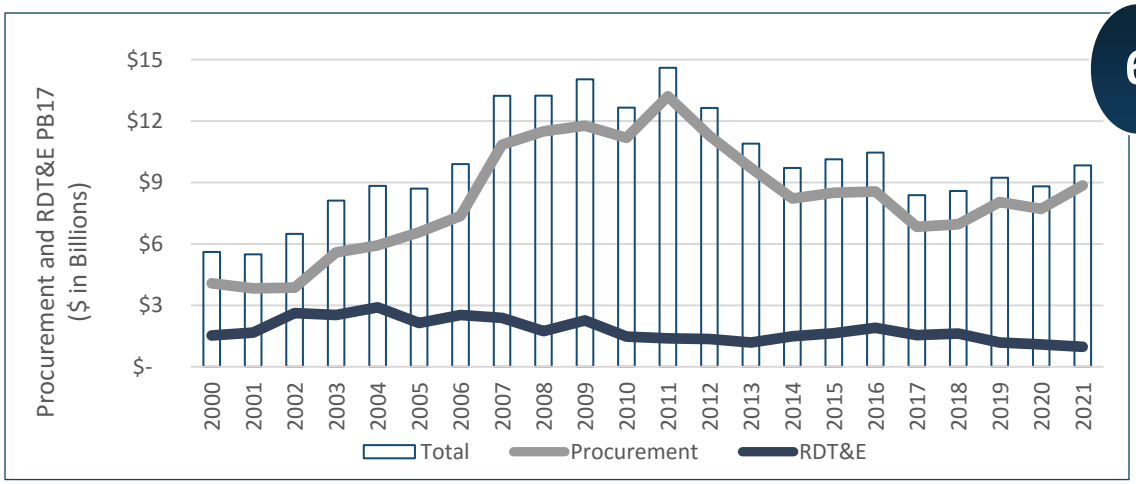
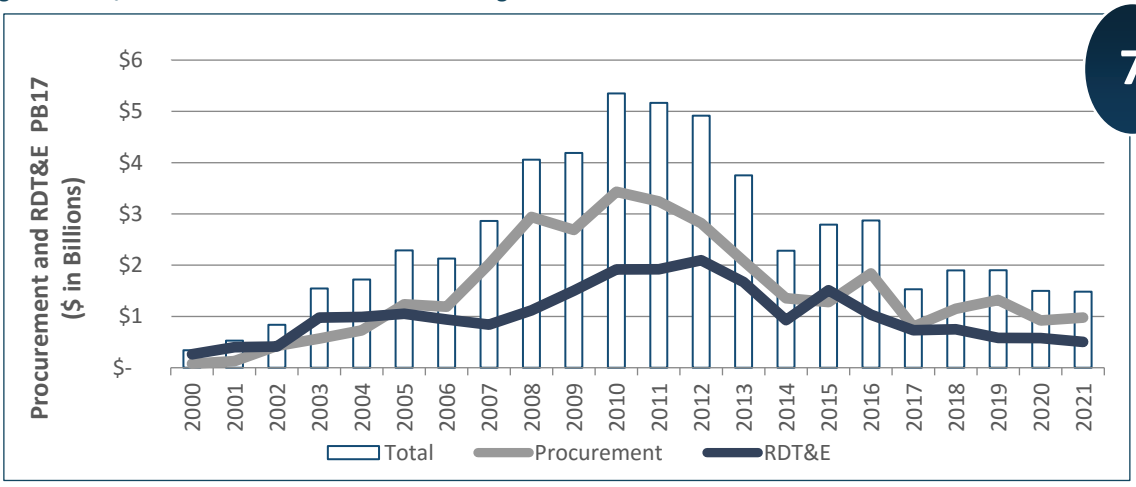


Figure 7: UAS/UAV Procurement and RDT&E Funding Profile



Source: Defense Resource Data Warehouse

Near-term DoD procurements forecasted for the FY2017 DoD budget are listed in Table 2. The Air Force is developing a trainer under the (T-X) program, which will replace its aging fleet of T-38 training aircraft with an advanced jet to train pilots flying-fifth generation fighter aircraft.

The Navy is introducing a new UAS system, known as the MQ-25A Stingray. MQ-25A replaces the Navy's Unmanned Carrier-Launched Airborne Surveillance and Strike (UCLASS) effort and refocuses it to be primarily a carrier-based unmanned aerial refueling tanker. The development of the MQ-25A stingray will be done alongside an additional buy of Boeing F/A-18 E/F Super Hornets over the next several years and accelerated purchases and development of the Lockheed Martin F-35 Lighting II Strike Fighter.

The Army is developing a new Future Vertical Lift (FVL) vertical lift capability. The concept incorporates new technology, materials, and designs that are quicker, have further range, provide better payload, are more reliable and easier to maintain and operate, have lower operating costs, and can reduce logistical footprints. The objective is to develop four different sizes of aircraft that will share common hardware such as sensors, avionics, engines, and countermeasures. FVL is meant to develop replacements for the Army's UH-60 Black Hawk, AH-64 Apache, CH-47 Chinook, and OH-58 Kiowa helicopters. The precursor for FVL is the Joint Multi-Role (JMR) demonstrator, which will provide technology demonstrations planned for 2017.

Table 2: Future Aircraft Programs (FY2016)

PROGRAM	TYPE	LEAD SERVICE	AWARD YEAR
Trainer (T-X)	Fixed Wing	Air Force	2017
CBARS	UAS	Navy	2018
FVL	Vertical Lift	Army	2022

Industry Suppliers

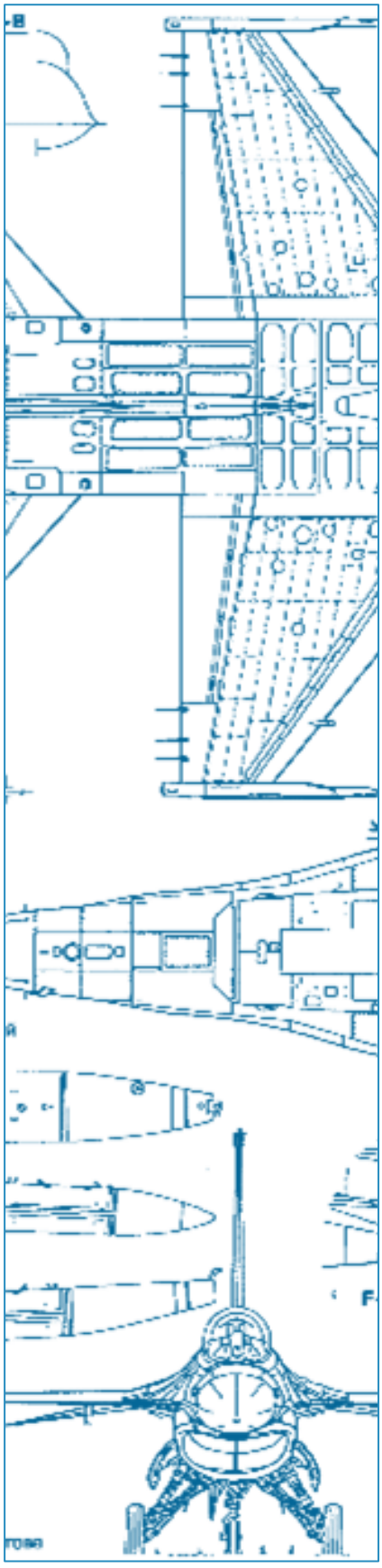
Six companies provide the majority of aircraft platforms and possess the full range of capabilities to bring a new weapon system from the research, design, and development phases into full production. The six firms are among the largest U.S. defense contractors, including Boeing, Lockheed Martin, Northrop Grumman, Bell Helicopter, Airbus Helicopter, and General Atomics. Many of the systems produced by each company are listed in Table 3.

Table 3: Prime Contractors for Major Aircraft Acquisition Programs

(Includes Previous Major Programs not Currently in Production)

Prime Contractor	Aircraft Sector: Fixed Wing	Aircraft Sector: Vertical Lift	Aircraft Sector: UAS
Airbus Helicopter		• Light Utility Helicopter	
Beechcraft	• T-6 Texan II		
Bell Helicopter		• AH-1 W/Z Viper • Huey • UH-1Y Venom • V-22 Osprey	
Boeing	• A-10 • B-1 • B-52 • EA-18G Growler • F-15 • F/A-18E/F Hornet • KC-46A • KC-135 • P-8A Poseidon	• AH-64D Apache New & Remanufacture • CH-47F Chinook • V-22 Osprey Fuselage	• RQ-21A Blackjack
Eurocopter		• UH-72A	
General Atomics			• MQ-1 Predator • MQ-1C Gray Eagle • MQ-9 Reaper
Lockheed Martin	• F-16 • F-22 • F-35	• MH-60 Assembly • Sikorsky's Product Lines* - CH-53K - MH-60S - UH-60 Blackhawk - VH-92A Presidential	• RQ-3 Dark • RQ-170 Sentinel
Northrop Grumman	• B-2 • B-21 • EA-6 Prowler • T-38		• MQ-4C Triton • MQ-8B Fire Scout • RQ-4 Global Hawk • MQ-8C Fire Scout • RQ-180

***In 2015, Lockheed Martin Corporation acquired Sikorsky Aircraft, a world leader in military and commercial vertical lift aircraft.**



Risk Assessment

The Department is focusing on defense unique aerospace capabilities that could be at risk and that are not sustained by the commercial market. The main concern is the industry's ability to sustain the design and manufacturing skills and capabilities needed for future aircraft design and manufacture.

Long Term Challenges

There has been a steady decline in the number of defense development programs for fixed-wing and vertical lift aircraft. Modernization programs will help sustain important capabilities but will not provide opportunities for major design, development and integration work. With the approaching end of development programs and an absence of new requirements in the next five to seven years, critical design capabilities will atrophy and ultimately experience shortages.

Design shortfalls are also projected because much of the defense aerospace workforce is close to retirement and the pool of young engineers available to replace them is dwindling. Opportunities for hands-on, real-time transfer of knowledge has been very limited. Therefore, future technical challenges are likely to be tackled by engineers with significantly less experience than the generation before. Consequences may include longer and more expensive development and initial production costs.

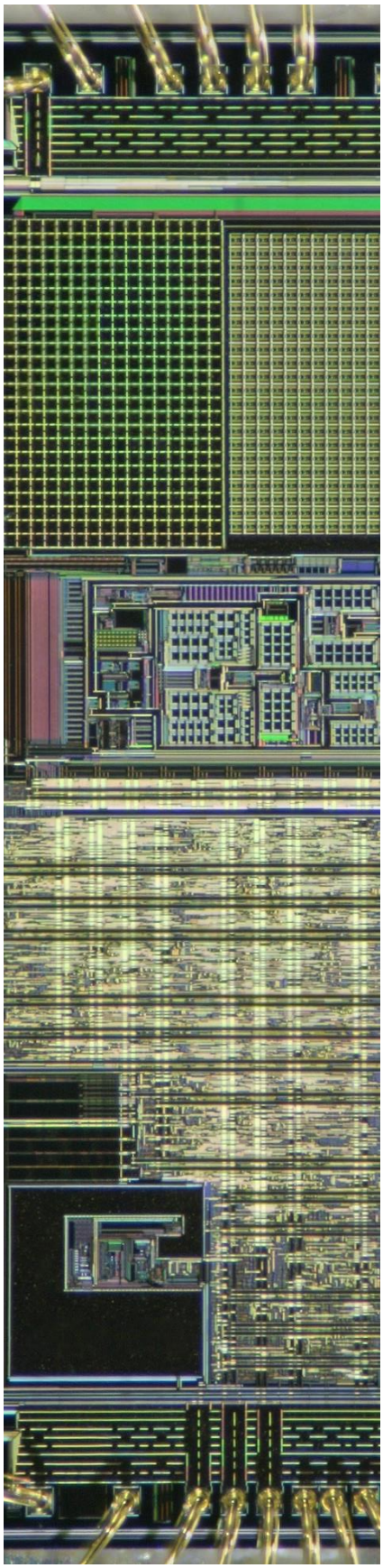
Main challenge is industry's ability to sustain design and manufacturing capabilities

Mitigation Efforts

The Aerospace Innovation Initiative is a DoD initiative to ensure that the United States can maintain air dominance in future contested environments. The purpose of this program is to design and demonstrate advanced aircraft technologies and reduce the lead time for future systems while strengthening the nation's critical defense-industrial-base design teams. Under the program and in partnership with the Air Force and the Navy, Defense Advanced Research Projects Agency (DARPA) will develop and demonstrate technologies that enable cost-effective air warfare capabilities for defeating future near-peer threats.

R&D investments in technology programs to satisfy future requirements will also allow DoD to sustain design teams, maintain competition in critical areas, and promote industry innovation. For example, the Adaptive Engine Transition Program is allowing Pratt & Whitney and General Electric to work on the development of a new engine that will increase fuel efficiency and power.

DoD is also working on platform requirements for the next-generation vertical lift systems through the FVL program and JMR technology demonstrators. It is expected that these efforts will help maintain vertical lift critical engineering design and manufacturing skill sets to remain productive and operational.



Electronics Sector Industrial Summary

Industry Overview

The modern electronics industry is a two-trillion dollar-plus industry that manufactures products for a wide variety of end user markets, including consumer electronics, computers, automotive, industrial equipment, medical equipment, telecommunications, and aerospace/defense. Although electronic systems and components are ubiquitous throughout all DoD weapons systems, global military production represents only 8.5% of a market that is dominated today by commercial devices.[28] The overall industry can be considered as a supply chain made up of five levels:

- **Design:** Engineering companies that design Integrated Circuits (ICs) and companies that develop software tools to enable design.

- **Front End Manufacturing:** Companies ("fabs") that manufacture ICs and companies that supply them with equipment and materials.

- **Back End Manufacturing:** Companies that assemble ICs into packages and manufacture packages.

- **IC Vendors:** Companies that design and market various types of ICs, such as high performance logic, memory, and analog. Companies that perform their own manufacturing are known as Integrated Device Manufacturers (IDM).

- **System and Integration:** Companies that combine ICs into electronic systems such as PCB manufacturers, and companies that integrate electronics for final military systems.

[28] "World Electronic Equipment Production by Type @ 2014 Exchange Rates", *Electronic Outlook*, September 2015.

Electronics are a key component in all modern defense programs

This summary focuses on three aspects of the electronics supply chain: microelectronics, encompassing the design and fabrication of ICs at micrometer and below scales; supply chain integrity, specifically counterfeit ICs and defense-specific trust and assurance requirements; and PCB manufacturing. While all of the above have commercial and defense-specific aspects, DoD continually evaluates the health of the entire electronics supply chain throughout the year.

Budget Considerations

Electronics is a key component of all modern defense programs, and so it is difficult to determine the percentage of the overall DoD budget that is spent on procurement in this area. An indication of the importance of this area can be found in the DoD FY2016 budget overview. Eight key capability areas are defined, with six directly related to advanced electronics.[29] One area is Nuclear Deterrence, where a main goal is "modernizing the triad's essential nuclear delivery systems". The availability of advanced strategically radiation hardened electronics will be a key enabler. A second example is Missile Defense where there will be a focus on investments in "discrimination capabilities and sensors".

DoD also supports the electronics industrial base through R&D funding. A review of DoD RDT&E budget for FY2016 shows ~$1.5 billion in funding requests for projects directly related to electronics, which is approximately 2% of the total DoD RDT&E budget.[30] DARPA and industry, for instance, co-fund the Semiconductor Technology Advanced Research Network (STARnet), a collaboration to drive electronics innovations benefiting both commercial and military applications. Raytheon, United Technologies, Texas Instruments, IBM, Intel, and semiconductor companies Micron Technology and Global Foundries are STARnet members. DARPA has also aggressively pursued individual collaborations with private sector electronics firms (e.g., NVIDIA, Analog Devices, Altera, Cadence, Synopsys, Invensense, Jariet Technologies, Jazz Semiconductor, Kilopass Technology, Xilinx, Keysight Technologies, Flex Logix, National Instruments, and others) to develop, expedite, and provide Government access to new technologies.

[29] "United States Department Of Defense Fiscal Year 2016 Budget Request: Overview," February 2016.
[30] "RDT&E PROGRAMS (R-1)," Department of Defense Budget Fiscal Year 2016.

Industry Suppliers

Electronics is a global industry, with supply chains that span multiple countries and regions. This high degree of interdependency among suppliers has profound implications for DoD to meet its requirements.

Microelectronics

Semiconductor ICs are the lowest level of the electronics supply chain, and are the most critical and technologically advanced. According to the Semiconductor Industry Association in its May 2016 report, "Beyond Borders: The Global Semiconductor Value Chain," the U.S. currently produces ~51% of ICs/semiconductors in the world.[31] However, the semiconductor supply chain is globalized and highly interdependent, as indicated in Figure 8; a typical IC manufacturing process involves more than four countries and more than three trips around the world[32].

Asia, where much of electronics production takes place, is by far the largest customer of U.S semiconductor companies, accounting for 62% of all U.S. sales. Sales to China alone account for half of these. U.S. companies continue to dominate the Chinese market with 56% market share. Since 2001, sales to the Asia Pacific market outside of Japan accounts for most of the growth in the global semiconductor market, which has quintupled in size from $39.8 billion to over $200 billion in 2015, including a $98.6 billion market in China alone (~8% increase over 2014).

The U.S. semiconductor industry's strength lies in microelectronics design using the fabless semiconductor model, focusing on IC design and outsourcing fabrication to dedicated foundries. Increasingly, however, these fabless companies are investing in design capabilities and services offshore.

As shown in Figure 9, consumer products such as cell phones, computers, and automobiles drive global semiconductor sales. Worldwide semiconductor sales have experienced steady growth over the past two decades, rising over 200% from $101.9 billion in 1994 to $335.2 billion in 2015. During the same period, U.S. sales increased almost 300% from $44.2 billion to $166 billion, despite a 4% drop from 2014. In 2015, semiconductors were the U.S.'s third largest export by value (>$40 billion) after aircraft and automobiles. It is estimated that the U.S. semiconductor industry accounts for 250,000 direct U.S. jobs and indirectly supports over 1 million.

Staying competitive requires a significant investment in R&D, new plants, and new equipment. The U.S. semiconductor industry spends roughly 30% of its sales on R&D and capital expenditures annually. Annual R&D expense as a percent of sales is more than any other U.S. industry.

[31] Semiconductor Industry Association, "Beyond Borders: The Global Semiconductor Value Chain," May 2016.

Figure 8: IC Manufacturing in a Globalized Independent Supply Chain

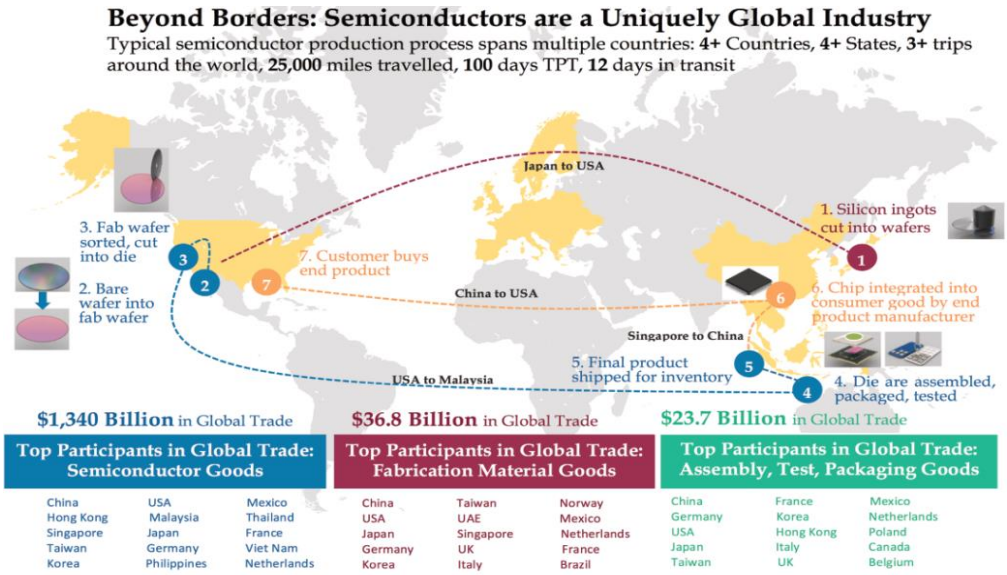
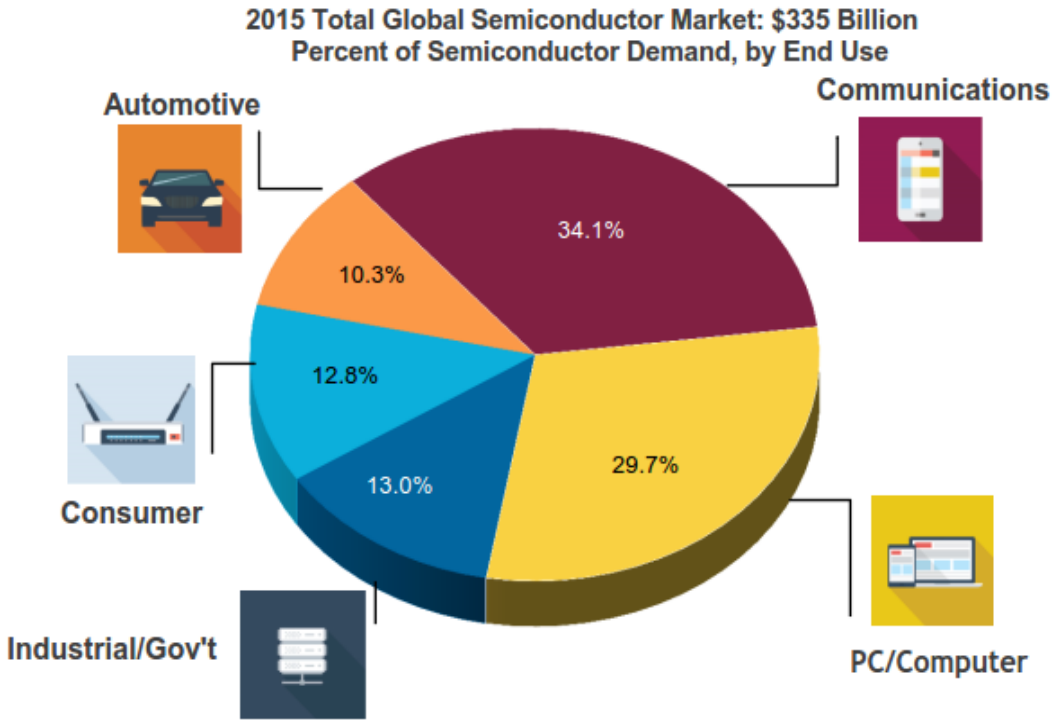


Figure 9: Percent of Semiconductor Demand by End User



Supply Chain Integrity

Application-specific integrated circuits (ASICs) are custom-designed, custom-manufactured ICs tailored for a specific purpose or functionality. DoD uses these custom-design ASICs in critical military systems when performance and power requirements cannot be achieved by other device types, such as microprocessors and Field Programmable Gate Arrays (FPGAs). These custom ASICs must be procured from trusted suppliers accredited by the Defense Microelectronics Activity (DMEA) through the DoD Trusted Foundry program.[33,34] DMEA accredits Trusted suppliers in the areas of integrated circuit design, aggregation, broker, mask manufacturing, foundry, post processing, packaging/assembly and test services. There are currently 72 DMEA-accredited suppliers covering 153 services, including 22 suppliers that can provide full-service trusted foundry capabilities.[35]

DoD relies on commercial suppliers and supply chains for all other non-trusted electronics requirements.

Printed Circuit Board

PCBs provide the substrate and interconnects for the various ICs and components that make up an electronic system. Like the overall electronics market, the global PCB market has experienced explosive growth—from $30 billion in 2000 to $60 billion in 2015.[36]

[33] "Protection of Mission Critical Functions to Achieve Trusted Systems and Networks," DoD Instruction 5200.44.
[34] Trust is the confidence in one's ability to secure national security systems by assessing the integrity of the people and processes used to design, generate, manufacture and distribute national security critical components such as microelectronics. For additional information see http://www.dmea.osd.mil/trustedic.html.
[35] Ibid.
[36] World Electronic Circuits Council (WECC), "WECC Global PCB Production Report for 2015", *WECC*, October 2016.

Risk Assessment and Mitigation Efforts

Weapons systems do not represent a significant share of the electronics market; therefore, the Department is subject to commercial market forces, including obsolescence, foreign investment, economic fragility, global supply chains, and consolidation. Within the three electronics focus areas we have identified five challenges described below that we are monitoring closely.

Microelectronics

Strategic Radiation Hardened Electronics

Strategic Radiation Hardened (SRH) Electronics are a critical component of the nuclear deterrent. These components must be able to withstand short bursts of intense radiation and high temperatures in order to satisfy mission requirements. These requirements have no analogue in the commercial world, and so this critical capability is continually at risk due to changing business conditions or technology obsolescence.

DoD recognizes the industrial base risk associated with SRH and has long been focused on this area. To mitigate this concern, the DoD has implemented a wide range of actions, described below. DoD plans to continue focus on this area and is currently in process of releasing a briefing in response to congressional directive HR 114-537, page 315: "Trusted Foundries for Strategic-Hardened Microelectronics."

DoD continues to ensure a domestic source of SRH microelectronics through a multifaceted approach. This includes investing in research and development on radiation hardening design techniques and radiation effects on state-of-the-art (SOTA) and state-of-the-practice semiconductor technologies, broadening the strategic microelectronics supplier base by developing alternate trust models, processes, and techniques, and continuing to work closely with partners in strategic community.

Trust is the confidence in the ability to secure national security systems by assessing the integrity of the people and processes used to design, generate, manufacture, and distribute national security critical components

The Defense Threat Reduction Agency (DTRA) manages the long-term radiation tolerant microelectronics program,[37] which focuses on SRH technology. DTRA has leveraged space radiation technology developed by the National Reconnaissance Office (NRO) to demonstrate strategic hardness of Radiation Hardened by Design (RHBD) libraries[38] and transition these libraries to commercial suppliers in the Trusted Foundry program.[39,40] RHBD libraries allow radiation hardened microelectronics to be built in standard commercial foundries, expanding the supplier base. In addition, DTRA and NRO fund academic radiation effects research at universities including Vanderbilt and Georgia Institute of Technology.[41]

Suppliers who focus on the commercial market (including SOTA foundries), are generally not willing or able to meet the personnel and facility requirements currently required to provide SRH components. To alleviate this concern, the FY2017 President's Budget requests funding the Office of the Assistant Secretary of Defense for Research and Engineering (OASD(R&E)) to execute the Trusted Foundry Long-Term Strategy investment program, comprising development of an alternative source for trusted SOTA photomasks, new trust approaches, microelectronics verification and validation capabilities improvement, and development of commercial standards for designing with trust and assurance.

DoD also continues to work closely with Radiation Hardened by Process facilities for legacy technology and specialty applications. DoD has previously engaged with these groups through the DPA Title III program. DoD also continues to maintain internal efforts such as the DMEA, DoD's organic capability for legacy and state-of-the-practice components and assemblies, which serves as the source of last resort for microelectronics that are no longer available from the industrial base.[42]

[37] "DTRA Radiation Hardened Micro/Nano Electronics Program," HASC Staff FY17 Budget Brief, March 18, 2016.
[38] Air Force Space Parts Working Group, "Advanced Technology Programs Group Radiation Hardened Branch Program: Overview and Status," April 28-29, 2016.
[39] "Rad Hard Electronics Industry Trends & Partially Depleted SOI," DTRA J9-NTSR, April 19-21, 2016.
[40] "Radiation Hardening By Design Phase 3 Final Report," HDTRA1-05-D-0001 TO-0003," April 8, 2016.
[41] "Georgia Tech Research Corporation $192,827.58 Contract Issued by Defense Threat Reduction Agency", http://government-contracts.insidegov.com/l/2321711/HDTRA113C0058, July 12, 2016.
[42] "Department of Defense: Defense Microelectronics Activity Business Model," www.dmea.osd.mil/bus_mod.html, June 7, 2016.

Secure Field Programmable Gate Arrays

FPGAs combine the programmability of processors with the performance of custom hardware. Because FPGAs can provide a useful balance between performance, rapid time to market, and flexibility, they are used in ~72% of Military and Aerospace systems.[43] FPGAs inherently provide some critical security benefits because sensitive design information is not programmed onto the device until it reaches the end user, making it harder for adversaries to target specific applications. [44] However, significant security concerns associated with FPGAs remain, including, threats to the integrity of the FPGA during manufacturing unauthorized access to the design bitstream and vulnerability to malicious design reconfiguration while in use. The United States has a strong position in FPGAs as greater than 90% of the commercial market is shared by three U.S. suppliers. Each of these companies has an extensive global supply chain that could provide opportunities for malicious tampering during manufacturing, and the programmable nature of these devices results in an inherent risk after the parts have been fielded.

DoD recognizes the need to balance system requirements and security concerns when considering FPGAs. To mitigate security concerns, DoD has implemented a wide range of actions. This includes leveraging existing United States Government (USG) and industry efforts, identifying related efforts to synchronize and eliminate single point solutions when possible, defining areas for investment, and ultimately developing a full trusted FPGA solution.[45] The three major vendors recognize this risk for their commercial business and have detailed security plans.[46] In addition, DoD has been actively engaged with these companies through venues such as the National Defense Industrial Association (NDIA) Trusted FPGA Workshop series.

[43] NSA, "Trusted FPGA & programmable System on Chip (PSoC) Agile Research/Prototyping Initiative," May 17, 2016.
[44] Ted Huffmire et al. "Managing Security in FPGA-Based Embedded Systems," 2008.
[45] Robert Gold, "Field Programmable Gate Array (FPGA) Assurance Workshop," Institute for Defense Analyses, May 17, 2016.
[46] For additional information see https://www.xilinx.com/, https://www.altera.com/, and https://www.microsemi.com/.

In order to go beyond commercial security offerings, DMEA and the National Security Agency (NSA), beginning in 2014, initiated a series of studies to assess the vulnerability of, and risks to, the FPGA supply chain and provide recommendations to address the identified supply chain risks.[47] These studies were led by DMEA and NSA, but included industry partners and stakeholders from across the DoD and Intelligence Community. These studies are being used to inform the DoD FPGA assurance strategy, which has recognized the FPGA design and bitstream as one of the key focus areas for FPGA assurance. In addition, these studies informed DMEA's development of the DoD Trusted Foundry Program's new Category II trust flow for standard parts that could be used to accredit an FPGA vendor's flow for trust.

DMEA facilitated a third study with Microsemi and Intel, Trust in FPGAs Feasibility Study (TFFS), which addressed aspects of the FPGA Hardware Study and Software Study and provided a systems-level approach. The TFFS study focused on a path to establish and implement a Category II Standard Part Trusted flow and a Trusted FPGA to include: Trusted FPGA design, third party intellectual property verification and validation, hard and soft intellectual property development and validation, mask manufacturing, wafer fabrication, packaging/assembly, test, and distribution. The DMEA TFFS study results estimated that the cost to design and manufacture a domestic Trusted FPGA via industry partnerships would be an estimated $65 million over two years if started concurrently with a commercial FPGA product family. If not starting concurrently with a commercial FPGA (having to pay 100% of the intellectual property and design cost) the cost is estimated to be upwards of $500 million. These efforts enabled the current DPA Title III effort studying the feasibility of establishing Trusted FPGA source(s) for an enterprise-wide DoD solution within commercial business models. AFRL is leading a Radiation Hardened Trusted FPGA Integrated Project Team (IPT) with DMEA, NRO, Space and Missile Systems Center (SMC), Missile Defense Agency (MDA), National Aeronautics and Space Administration (NASA), and others.

This effort is divided into two phases. Phase one of this effort is to work with the major FPGA suppliers to develop an approach to ensure the availability of an advanced, trusted FPGA technology, ready for space-grade/strategic radiation-hardened qualification, to support DoD/IC applications including satellite and strategic missile systems. The approach shall leverage the DMEA Category II Trusted FPGA design and manufacturing flow concept. This effort began in FY2016 and is expected to be completed in FY2017. The second phase of the effort is expected to implement some of the recommendations of the first phase to demonstrate the efficacy of the approach and the Category II flow. The DMEA Category II Trusted FPGA flow is being used as a baseline for the Broad Agency Announcement posted on August 9, 2016.

[47] DMEA, "Trust in FPGA Hardware Study," "Trust in FPGA Software Study," and "Trust in FPGA Feasibility Study," 2014.

Supply Chain Integrity

Trusted & Assured Microelectronics

Assuring the integrity of the microelectronics supply chain is becoming increasingly difficult. Globalization, increasing device complexity, low volumes, and small market share have increased the risk of supply chain attacks, placing DoD intellectual property at increased risk of theft by adversaries, and increasingly challenging DoD's ability to access leading-edge technologies. DoD recognizes that trusted and assured microelectronics are a critical building block of secure military systems. To mitigate these supply chain risks, DoD has implemented a wide range of actions, described below.

The FY2016 President's Budget funded the DoD Trusted Foundry Long-Term Strategy, resulting in the Trusted and Assured Microelectronics program being led by OASD(R&E). This program defines three goals for trust and assurance of defense microelectronics, i.e., access, assurance, and availability. Recognizing that trusted and assured supply of microelectronics is a USG-wide concern, this activity is interfacing with interagency partners to take into account interagency requirements, opportunities for collaboration, and strategic decisions that can be made to limit the overall cost of these requirements to the USG. It supports activities to ensure critical and sensitive integrated circuits are available to meet the DoD's needs and implements three integrated, complementary solutions that (1) provide for intellectual property protection of microelectronics components; (2) improve capability to evaluate and validate trust and assurance of microelectronic parts and advance standards to incentivize the commercial marketplace to recognize trust as a competitive design standard; and (3) develop and demonstrate alternative approaches to assuring the trust of the microelectronics supply chain in order to enable broader DoD access to commercial SOTA microelectronics technology.

The Department has a comprehensive policy for managing risks to DoD warfighting capability from foreign intelligence collection, hardware, software, and cyber vulnerability, and supply chain exploitation. The Department requires its acquisition programs to produce and maintain robust program protection planning throughout the acquisition life cycle.

The Program Protection Plan is the primary means by which the Department integrates assured microelectronics policy into program management, engineering, and the configuration, parts, and contract management disciplines. In 2014, the Department established a joint federated assurance center, federating expertise, tools, and methods to support acquisition program hardware and software assurance needs. Program protection planning gives special attention to ASICs. For ASICs that are custom designed, manufactured, or tailored for specific DoD military use, DoD requires they be procured from a trusted supplier accredited by DMEA.

DMEA manages the DoD Trusted Foundry Program. This program provides the Department, as well as the NSA and other agencies, with access to the trusted state-of-the-art microelectronics design and manufacturing capabilities necessary to meet the confidentiality, integrity, availability, performance, and delivery needs of USG customers. DMEA accredits suppliers as "trusted" in the areas of IC design, aggregation, brokerage, mask manufacturing, foundry, post processing, packaging/assembly, and test services. These services cover a broad range of technologies and are intended to support both new and legacy applications, both classified and unclassified. DMEA is also working with DoD's PCB Executive Agent (EA) to develop trust accreditation methodologies for PCB manufacturer, board design, and electronic assembly as a part of the trust accreditation portfolio. There are currently 72 DMEA-accredited suppliers covering 153 services, including 22 suppliers that can provide full-service trusted foundry capabilities.[48]

Additionally, DoD assesses the impact of foreign investments in the U.S. semiconductor industry through the CFIUS process. DoD is also investing millions of dollars to incentivize and grow on-shore microelectronics and other advanced manufacturing capabilities through the Manufacturing USA Institutes. Title III of the DPA allows DoD to improve industry's ability to preserve and expand supplies of defense critical microelectronics.

Counterfeit Parts and Materials

Counterfeit parts have the potential to delay missions and ultimately endanger service members. An increasingly globalized electronics industry increases the risk that these parts will enter the DoD supply chain. This risk has been recognized both inside and outside of the Department.[49]

DoD has implemented a wide range of actions to mitigate the risk of counterfeit electronic parts entering the supply chain. DoD takes a holistic risk-based approach to prevent infiltration of counterfeit parts and materials into the DoD supply chain through working with industry, establishing policy, and driving employee training and new technology.

In 2013, the Department established policy and assigned responsibilities with DoD Instruction (DoDI) 4140.67 to prevent the introduction of counterfeit materiel at any level of the DoD supply chain, including special requirements prescribed by section 818 of Public Law 112-81. DoD policy requires DoD Components to report all occurrences of suspect and confirmed counterfeit materiel to DoD criminal investigative organizations, and other law enforcement authorities at the earliest opportunity.

[48] For additional information see http://www.dmea.osd.mil/trustedic.html.
[49] GAO, "Counterfeit parts: DOD needs to improve Reporting and Oversight to reduce supply chain Risk," February 2016.

In addition, DoD Components must report occurrences of suspect and confirmed counterfeit materiel to deficiency reporting systems and the Government- Industry Data Exchange Program (GIDEP) within 60 days. DoD works with law enforcement on counterfeit investigations, and, where appropriate, debar companies and prosecute counterfeiters. In addition, the Defense Federal Acquisition Regulation Supplement (DFARS) to the Federal Acquisition Regulation (FAR) is continually updated to addresses counterfeit risk.[50]

The Department has strengthened its counterfeit parts mitigation capability through a number of technology initiatives. DLA checks and applies Deoxyribonucleic Acid (DNA) authentication technology to every microcircuit it procures (over 80,000 annually). The DNA mark enables rapid screening of the microcircuit throughout the supply chain and retrieval of pedigree information anytime throughout its life. Enhancements to DoD's Past Performance Information Retrieval Service – Statistical Reporting software provides contracting specialists the capability to identify high risk suppliers, parts that are at higher risk for counterfeiting as well as parts that are overpriced prior to contract award. DARPA has multiple programs related to supply chain integrity, designed to address both trusted and assured microelectronics and counterfeit parts and materials. For example, the Supply Chain Hardware Integrity for Electronics Defense program seeks to make counterfeiting too complex and time-consuming to be cost effective.

DoD has taken a risk-based approach to address counterfeit parts and materials, not only today but into the future. The Department has a robust process in place that will continue to evolve to address the ongoing challenge of counterfeit parts and materials introduction into the defense supply chain.

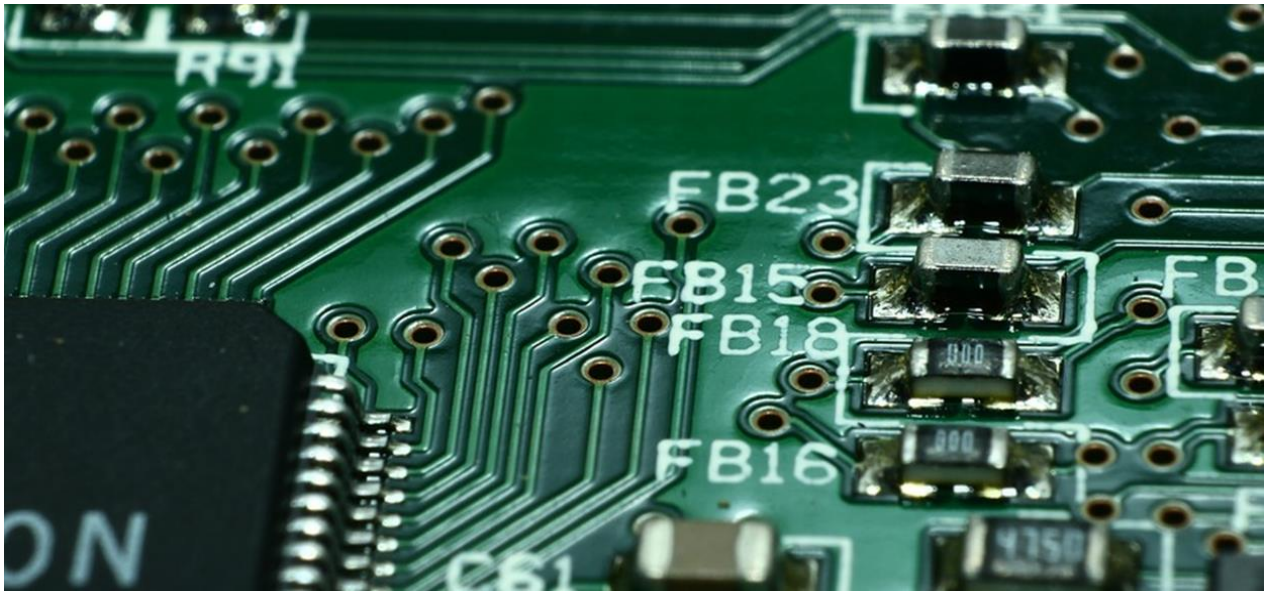
A risk-based approach allows DoD to address counterfeit parts and materials in the defense supply chain, not only today, but into the future

[50] DFARS Cases: (2012-D055) "Detection and Avoidance of Counterfeit Electronic Parts," and (2013-002) "Expanded Reporting of Non-conforming Items," (2012-032), "Higher Level Contract Quality Requirements," and (2014 –D005), "Detection and Avoidance of Counterfeit Electronic Parts – Further Implementation".

Printed Circuit Board

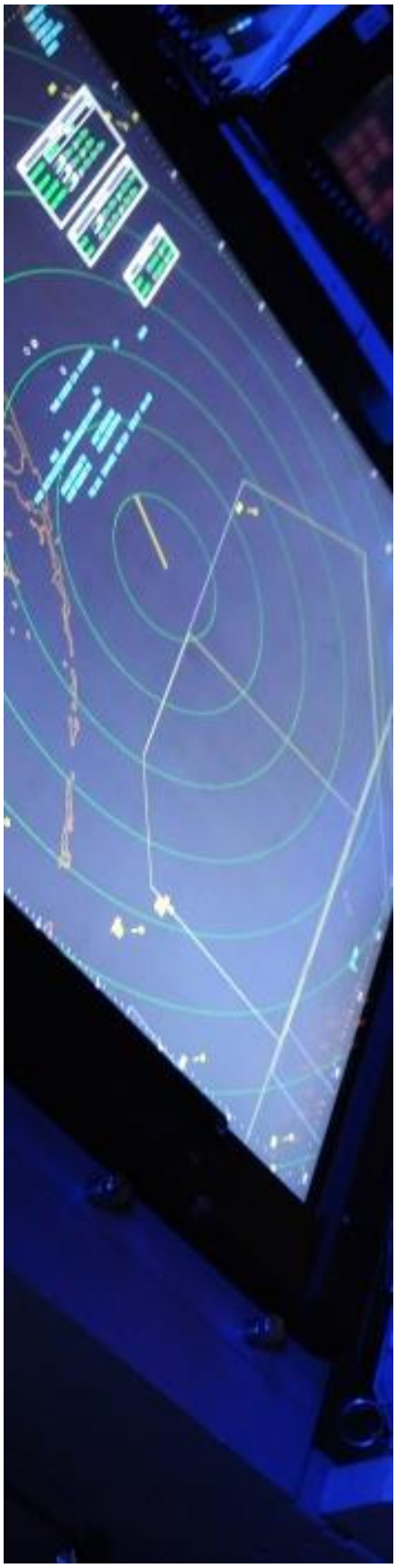
U.S. PCB manufacturing is struggling to remain current and relevant in the global marketplace. Today, 90% of worldwide PCB production is in Asia, over half of which occurring in China. The United States accounts for only 5% of global production, representing a 70% decrease from $10 billion to $3 billion.[51] The number of domestic PCB manufacturers has shrunk from more than 2,000 in the 1980s to 312 in 2016.[52] As a result, DoD is becoming increasingly dependent on foreign-sourced PCB products to meet critical military requirements, and U.S. manufacturers have become more dependent on DoD to remain viable. 99% of microcircuit/IC substrate production resides overseas, creating trust and supply chain availability concerns.

DoD recognizes the risks associated with the shrinkage of the PCB industry in the United States and has created an executive agent to focus on this issue. DoD has designated the Secretary of the Navy as the EA for PCBs and Interconnect Technology. The PCB EA provides solutions to ensure DoD has access to an assured PCB industrial base by investing at Naval Surface Warfare Center Crane Division and other DoD activities to sustain DoD organic knowledge and capability for PCB manufacturing and related issues. In addition to executing the study of field failures due to counterfeit parts, the PCB EA is engaged in several ongoing efforts, including a PCB industrial base assessment, PCB and interconnect technology roadmap development, and the development of a PCB manufacturer accreditation methodology for inclusion within the DMEA Trusted Supplier portfolio. These efforts will help to provide DoD access to a viable PCB industrial base, ensuring superiority and readiness.



[51] World Electronic Circuits Council (WECC), "WECC Global PCB Production Report for 2015", *WECC*, October 2016.
[52] H. Miller, "FabFile Online," http://www.fabfileonline.com.

Command, Control, Communications, and Computers Sector Industrial Summary



Industry Overview

Command, control, communications, and computers (C4) is an integrated system of doctrine, procedures, organizational structures, personnel, equipment, facilities, and communications designed to support a commander's exercise of command and control across the range of military operations to ensure the Warfighter receives jointly integrated and effective capabilities necessary to conduct operations. C4 programs consist of Major Defense Acquisition Programs (MDAP) and Major Automated Information Systems (MAIS) due to the larger network infrastructure.

C4 is comprised of the following functions:

- *Command and Control* provides the functional capabilities to control and manage sensors and weapons; connectivity to the Global Interface Grid for Joint operations; establishing Engage on Network capabilities; and providing mission command capability.

- *Communications Systems* ensure the ability to communicate both horizontally and vertically via voice and data within all mission areas and Combat Operational Environments, whether communicating with a ground, sea, air, or space platform.

- *Computers* process, coordinate, and distribute sensor and weapons data.

The global and commercial nature of this sector, coupled with the impracticality of thoroughly testing all elements of electronic hardware and software, makes supply chain management and anti-counterfeiting particularly important to this defense sector.

Budget Considerations

As shown in Figure 10 RDT&E budget grows sharply and then drops off as the programs transition to Procurement. Figure 11 shows the Procurement budget, which is scheduled to grow through 2021. Because of the depth and breadth of the industry, as well as the support of the commercial C4 industry, DoD does not have major concerns for the sector related to a future downturn.

Figures 10 and 11: C4 Funding Profiles

Figure 10: C4 RDT&E Funding

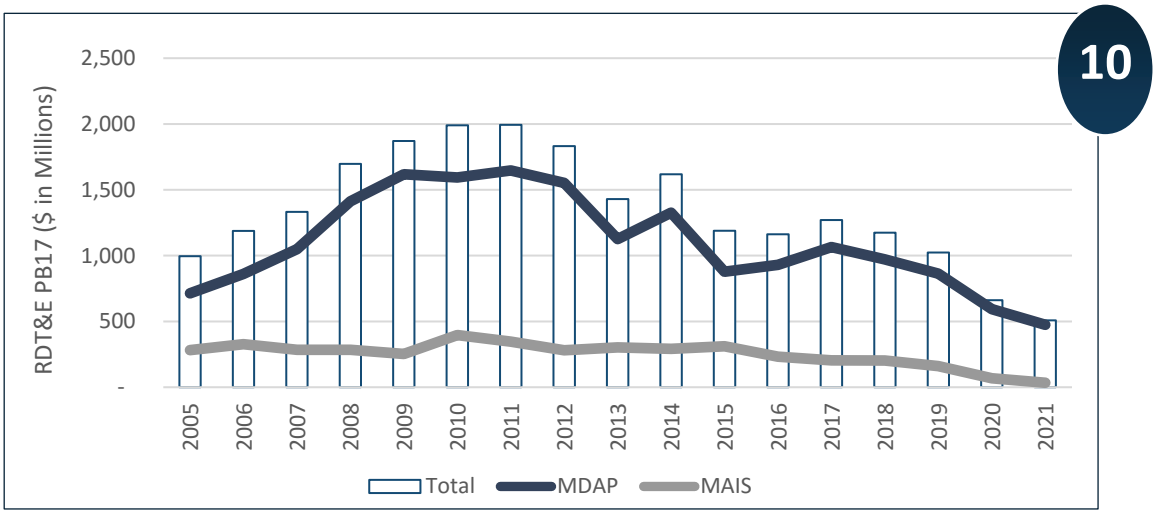
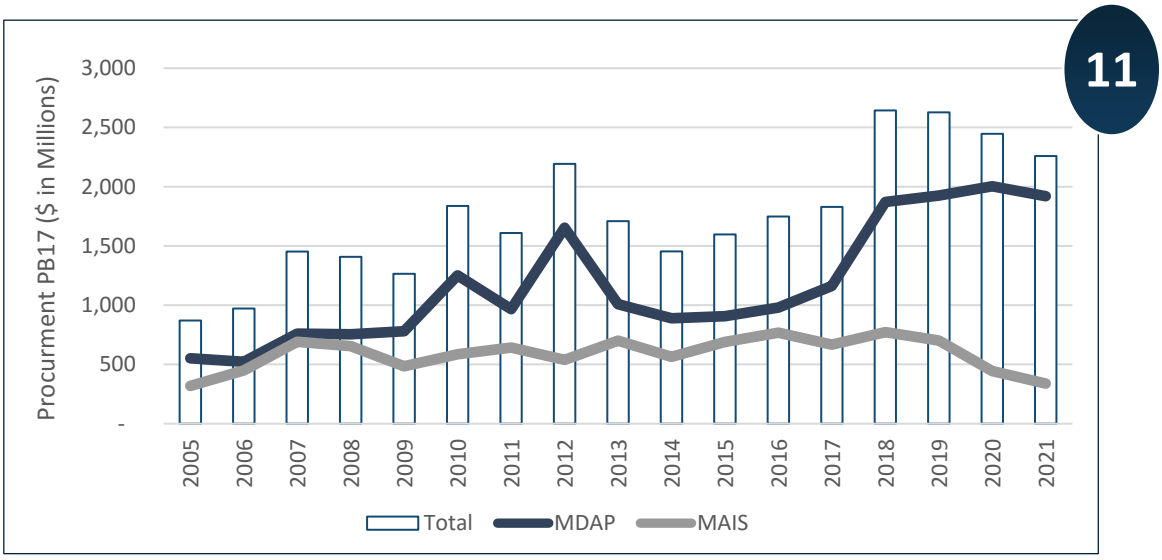


Figure 11: C4 Procurement Funding Profile



Source: Defense Resource Data Warehouse

Industry Suppliers

A diverse set of vendors are qualified to design and build defense products within the C4 industrial sector. A robust global commercial electronics industrial base supports these vendors. Second-tier suppliers of assembled components tend to serve both commercial and defense customers. Third-tier suppliers of individual components, such as integrated circuits, frequently supply identical products for both commercial and defense use. At the fourth-tier, such as design tools and reused intellectual property, there is frequently minimal awareness of the final end use in defense products. The C4 industrial base is largely global below the prime contractor tier.

Table 4 identifies the prime contractors for each MDAP in FY2016. Table 5 identifies the prime contractors for each MAIS in FY2016.

Table 4: C4 MDAP Prime Contractors

MDAP	PRIME CONTRACTORS
Airborne/Maritime/Fixed Station Joint Tactical Radio System (AMF JTRS)	Being Restructured (No Contract)
Cooperative Engagement Capability (CEC)	Raytheon
Family of Advanced Beyond Line-of-Sight Terminals (FAB-T)	Raytheon
GPS Next Generation Operational Control System (OCX)	Raytheon
Integrated Air & Missile Defense (IAMD)	Northrop Grumman
Joint Precision Approach and Landing System (JPALS)	Raytheon
JTRS Handheld, Manpack, and Small Form Fit (HMS)	Thales/General Dynamics
Multi-Functional Information Distribution System (MIDS)	Rockwell Collins / BAE
Navy Multiband Terminal	Raytheon
Warfighter Information Network–Tactical (WIN-T) Increment 2	General Dynamics
WIN-T Increment 3	General Dynamics

Table 5: C4 MAIS Prime Contractors

MAIS	PRIME CONTRACTORS
Air and Space Operations Center-Weapon System (AOC WS)	Northrop Grumman
Common Aviation Command and Control System (CAC2S)	General Dynamics
Consolidated Afloat Networks and Enterprise Services (CANES)	BAE Systems/General Dynamics/C4 Systems/ Global Technology Systems/Northrop Grumman/Serco
Distributed Common Ground System-Army (DCGS-A)	General Dynamics
Mission Planning System (MPS)	DCS/BAE Systems
Tactical Mission Command (TMC)	General Dynamics

Main challenge is to ensure defense unique applications continue to be developed amidst strong commercial market

Risk Assessment

The long term challenge for C4 systems is to reduce the size, weight, and cost, while improving performance and keeping up with technology. This is especially true for the Warfighter for whom improved global positioning systems (GPS) and communication hand-held receivers are vital to perform both strategic and tactical maneuvers with a high degree of confidence and success.

Mitigation Efforts

Defense unique areas associated with military graded GPS receivers has been mitigated through the DoD Title III program. The Low Cost Military GPS Receivers Project created domestic production capabilities for essential subcomponents for the Defense Advanced GPS Receiver (DAGR) to pursue methods for reducing weight, size, power-consumption and cost, while improving performance capabilities.

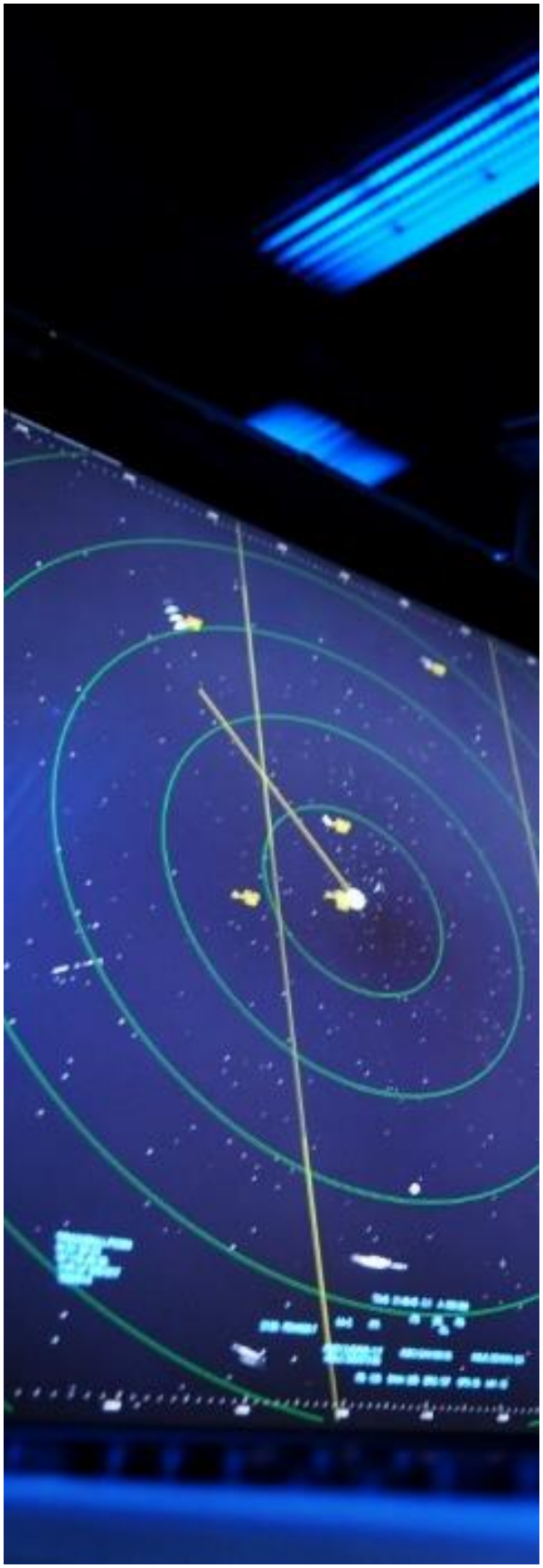
Radar and Electronic Warfare

Industry Overview

Military radar and electronic warfare (EW) systems continue to be upgraded or replaced with Active Electronically Scanned Arrays (AESAs). Industry has been expanding capacity in areas where processes and facilities are specific to AESA. Two types of facilities have been identified as essential to AESA manufacturing: Semiconductor/Captive Monolithic Microwave Integrated Circuit (MMIC) Foundries that manufacture MMICs; and Micro-Electronic Manufacturing/Assembly Facilities capable of producing AESA solid-state devices such as Transmit/Receive (T/R) Modules, Subassemblies, and Beam formers in Multiple Frequency Bands.

Engineering skills specific to AESA development are well staffed and there is no anticipation of a shortage of any skilled engineering professionals now or in the future.[53] Engineering staffs required for the design/development of AESA products were brought in early in the process and remain today. Most of the skills required in design, manufacture, and testing of AESAs are not unique to the AESA industry.

With several full rate production (FRP) programs previously developed for AESA upgrades to air, sea, and land systems, as well as foreign sales, the industrial base appears to be viable and stable.



[53] Office of the Deputy Assistant Secretary of Defense for Manufacturing and Industrial Base Policy and the Defense Contract Management Agency/Industrial Analysis Center, "Surface AESA Radar Industrial Base Assessment," October 2013.

The radar and EW markets continue to grow. Nevertheless, radars make up only a small part of the electronics market and AESA makes up only a small part of the radar market, so a future downturn in funding for AESA systems will not affect the overall market. Figure 12 illustrates RDT&E funding and Figure 13 illustrates procurement funding for radar and EW. Funding for radar and EW markets is cyclical, RDT&E funding rises sharply and then drops off as the programs transition to procurement.

Figures 12 and 13: Radar and EW Funding Profiles

Figure 12: Radar and EW RDT&E Funding Profile

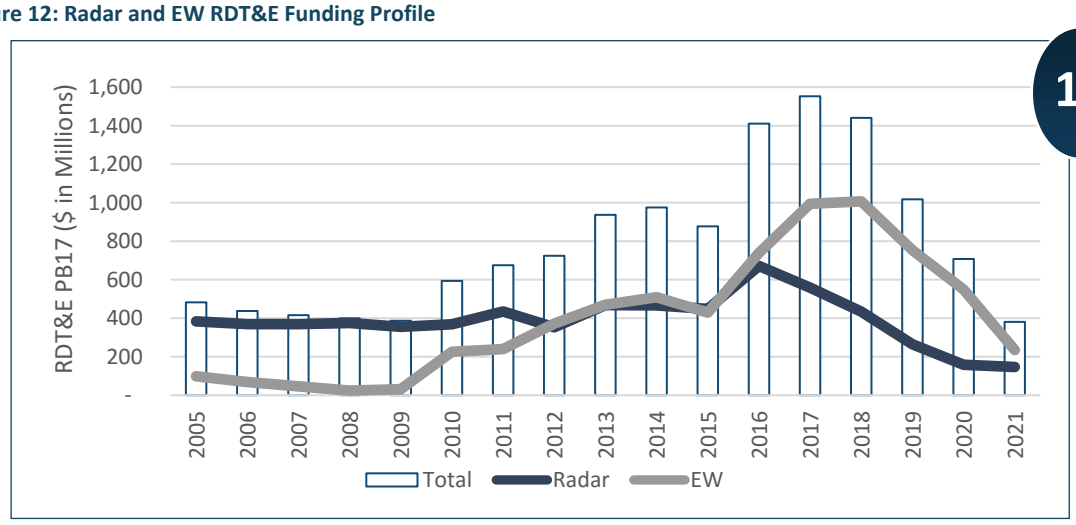
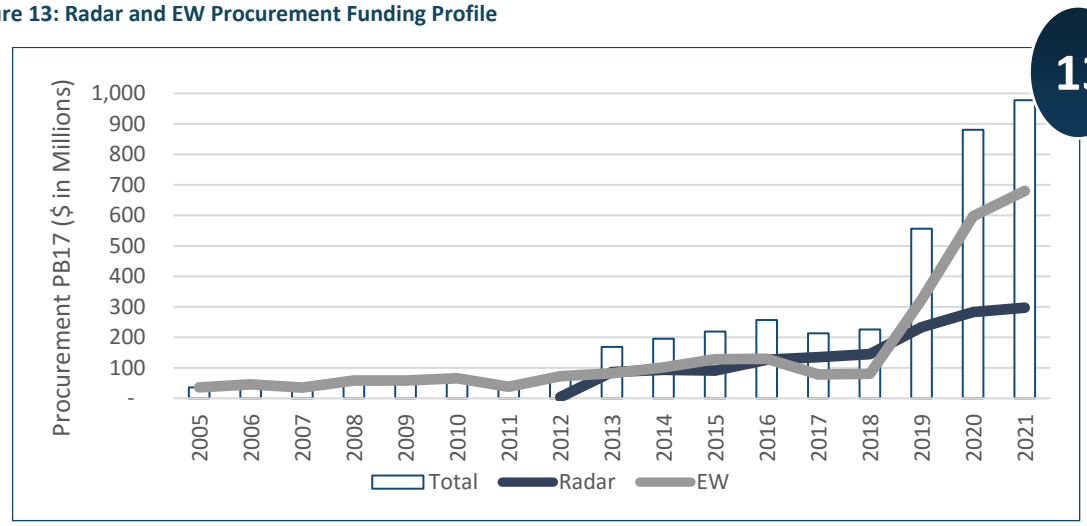


Figure 13: Radar and EW Procurement Funding Profile



Source: Defense Resource Data Warehouse

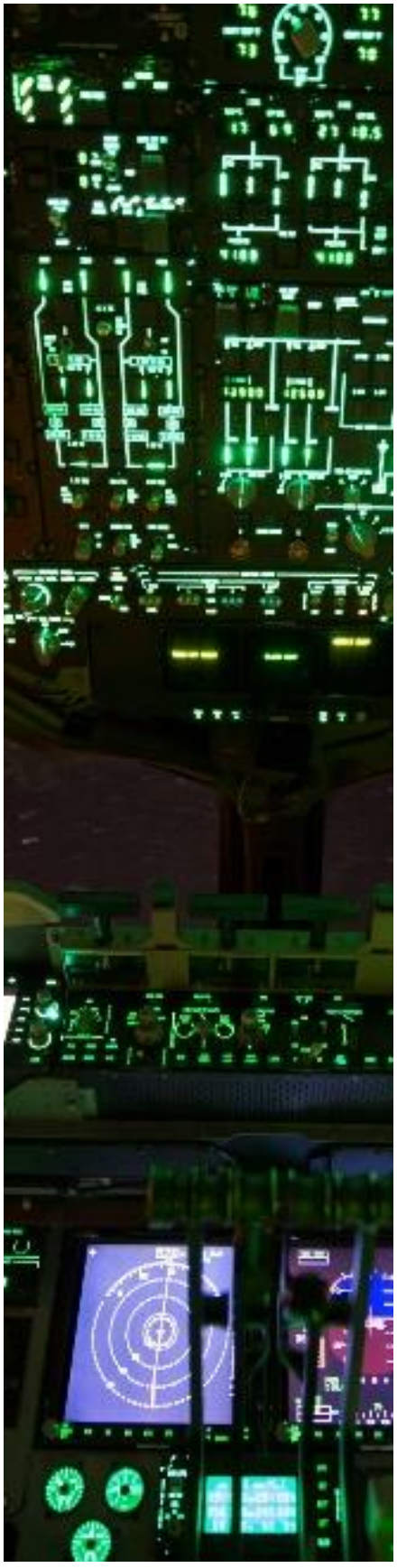
Industry Suppliers

In FY2016, three domestic prime manufacturers dominated the radar sector (Raytheon, Lockheed Martin, and Northrop Grumman) and four domestic prime manufacturers dominated EW (Raytheon, Northrop Grumman, Harris, and BAE Systems) for six acquisition programs in the EMD phase and two programs in production as identified in Table 6.

Table 6: Prime Contractors for Major Radar Programs

RADAR SECTOR

PRIME CONTRACTOR	RADAR	SERVICE	AWARD DATE
BAE Systems / Harris	• Integrated Defensive Electronic Countermeasures (IDECM)	• Navy	
Lockheed Martin	• Space Fence	• Air Force	• October 2015
	• Long Range Discrimination Radar (LRDR)	• MDA	• October 2015
Northrop Grumman	• B2 Defensive Management System Modernization (DMS-M)	• Air Force	• March 2016
	• Common Infrared Countermeasures (CIRCM)	• Army	
	• Ground/Air Task Oriented Radar (G/ATOR)	• Marine Corps	• August 2016
Raytheon	• Air and Missile Defense Radar (AMDR)	• Navy	• April 2016
	• Next Generation Jammer (NGJ)	• Navy	• April 2016
	• Three-Dimensional Expeditionary Long-Range Radar (3DELRR)	• Air Force	• 2017



Risk Assessment

Tactical airborne AESA radar systems for fighter aircraft are a critical niche capability for the Department and is an at-risk area as there are only two sources for these radars currently in production or sustainment for the F-35, F-22, F/A-18E/F, F-15, and F-16. However, tactical airborne radar system production for all but the F-35 will wind down within the Future Years Defense Program (FYDP), increasing the risk of reduced competition and innovation in this area.

Long Term Challenges

The primary challenges AESA technology encounters in today's marketplace are affordability, increased foreign competition, and limited access to foreign markets by U.S. firms. Companies report that, until recently, the United States had maintained a lead in defense technology development and capability. Over the past decade the gap in these two areas has decreased. This is highlighted by the fact that, as recently as 10 years ago, the United States provided the majority of defense systems sought by our foreign allies and partners. This position is changing. In 2010, European and Israeli defense companies accounted for greater than 50% of the sales in the non-U.S. defense electronics market. These increased sales by foreign companies highlight foreign technical capabilities. As a byproduct, the expansion of sales will provide investment funds for further development. Since 2000, defense companies have proliferated globally, maturing and creating new and advanced products. This is due to allied/partner ambition to build organic capacity and boost defense export. Beyond enhancing competition, expanding sales to countries with burgeoning defense electronics industries will require co-development and an increased amount of technology transfer. Many European defense firms are now multi-domestic and may become multi-national in the future.

Mitigation Efforts

Capacity issues are continually assessed by all manufacturers to assure current and planned requirements can be satisfied. However, rapid swings in requirements (either upturn or downturn) can impose stress on available technically qualified engineering and manufacturing personnel. For this reason, industry employs many strategies to train and maintain its workforce. Some of these strategies include on-site training, coordination with universities via co-ops and degree programs, certifications for technicians and operators, partnerships with their other manufacturing sites, and working relationships with local contracting firms to provide talent on an as-needed basis.

Use of common manufacturing processes and specialized work cells leverages the experience and expertise of highly trained personnel and minimizes redundancy in specialized equipment dedicated to particular programs. Resources are easily shared or shifted among various programs to satisfy customer demands. Commonality in hardware also provides leverage and allows for simultaneous scheduling of multiple programs.

Trends toward commonality in hardware have also increased the use of specialty shops or centers of excellence such as machining, electronics, and fabrication. Most prime system integrators use a captive manufacturing process drawing on the expertise of sister facilities located throughout the country, and/or the world, to provide additional support and address capacity issues.

Mitigating the reduced competition and innovation risks for tactical airborne radar systems will require stable research and development investment for next generation AESA technologies to preserve a competitive industrial base.

There are currently three ongoing Title III projects relevant to the technologies utilized in AESAs:

- *GaN Radar and Electronic Warfare MMIC*
  The purpose of this $21.1 million project is to increase the yield, affordability, and availability of MMICs produced on 100 mm Gallium Nitride epitaxy on Silicon Carbide substrates.
- *GaN X-Band MMIC*
  The purpose of this $11.3 million project is to increase the yield, affordability, and availability of X-band MMICs produced on 100 mm Gallium Nitride epitaxy on Silicon Carbide substrates.
- *GaN Advanced Electronic Warfare MMIC*
  The purpose of this $17.1 million project is to establish a domestic, economically viable, open-foundry merchant supplier production capability for Ka-band GaN MMICs.

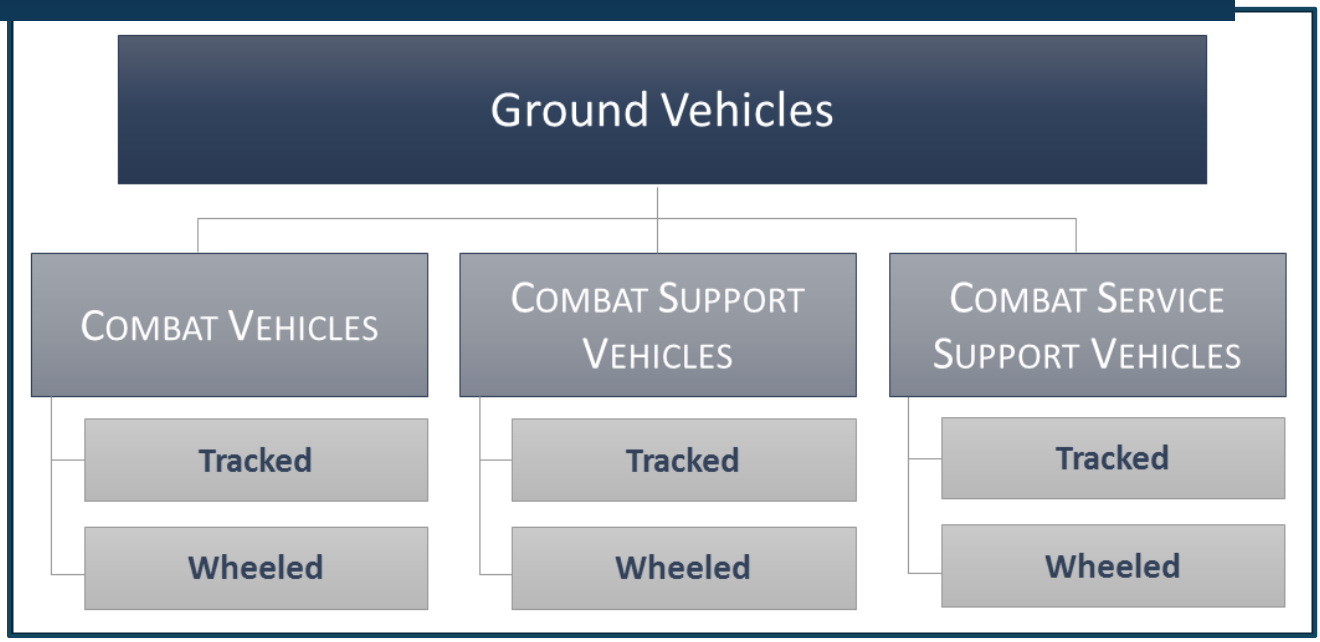
Ground Vehicles Sector Industrial Summary

Industry Overview

The Ground Vehicle Portfolio is coming off a period of large growth in demand from the Services, ample Overseas Contingency Operations funding, and recent program decisions. The equipment is almost exclusively defense unique. The future of this sector is dominated by a competition for funding between new programs that have recently passed or approach milestone B (Joint Light Tactical Vehicle (JLTV), Armored Multi-Purpose Vehicle (AMPV), and Amphibious Combat Vehicle (ACV)), with improvements to existing capabilities (Bradley, M1A1/M1A2, M109), as well as fleet maintenance and sustainment efforts (Amphibious Assault Vehicles (AAV), Medium Tactical Vehicle Requirement (MTVR), High Mobility Multi-Purpose Vehicle (HMMWV), Light Armored Vehicle (LAV), Stryker, and many others).

This sector is divided into three sub-sectors based on intended use as depicted in Figure 14. Industry is correspondingly similarly organized with some overlap between major manufacturers. The three vehicle sub sectors are: Combat, Combat Support (CS), and Combat Service Support (CSS).

Figure 14: Ground Vehicle Taxonomy



- Combat Vehicles include tanks, Infantry Fighting Vehicles (IFVs), Armored Personnel Vehicles (APCs), and LAV. Combat vehicles are vehicles that are designed for direct contact with the enemy. Combat vehicles are armored to some level of protection, except for Internally Transportable Vehicles (ITVs), which trade protection (weight) for transportability by intra-theater aircraft.

- Combat Support Vehicles directly support Combat vehicles and troops with firepower or mobility. These include self-propelled artillery, AAV, and Multiple Launch Rocket Systems (MLRS). Many of these vehicles are armored and armed due to their proximity to the combat area.

- Combat Service Support Vehicles include light, medium, and heavy truck fleets, utility vehicles, special purpose vehicles, and recovery vehicles. They can be armored or have applique armor packages applied depending on where on the battlefield they might appear. They support critical sustainment functions including supply, maintenance, explosive ordinance disposal, medical, human casualty evacuation, vehicle casualty evacuation, general transportation, communication, and general utility.

Table 7 identifies vehicle types, purposes, and activities.

Table 7: Ground Vehicle Overview

VEHICLE TYPE	VEHICLE EXAMPLE	PURPOSE	ACTIVITIES
Combat 	● M1A1/M1A2 ● Stryker ● Bradley ● LAV ● ITV	Close with and destroy enemy units or repel enemy units with high mobility protected firepower and crew or troop protection.	● Direct Fire ● Attack ● Defense ● Crew and Troop Protection *In the case of ITV's the vehicles trade protection for operational mobility to rapidly conduct or support tactical operations through use of intra theater aviation support.*
Combat Support 	● M109 Paladin ● MLRS ● AAV ● MRAP ● HIMARS	Support combat units and personnel from behind the combat units with fire support or specific mission activities on demand.	● Artillery, Rocket, and Mortar fires ● Amphibious Operations ● Route Clearance
Combat Service Support 	● JLTV ● MTVR ● FMTV ● FHTV ● Hercules ● HEMTT ● HMMWV ● LVSR	Provide support and services to ensure freedom of action, extended operational reach and prolonged endurance.	● Transport of all classes of supply. ● Movement of human and maintenance casualties, POW's and displaced persons. ● Rearward from a logistics release point and distribution onward to Combat and Combat Support Units, as appropriate, on any terrain and all weather conditions.

Combat Vehicles

Budget Considerations

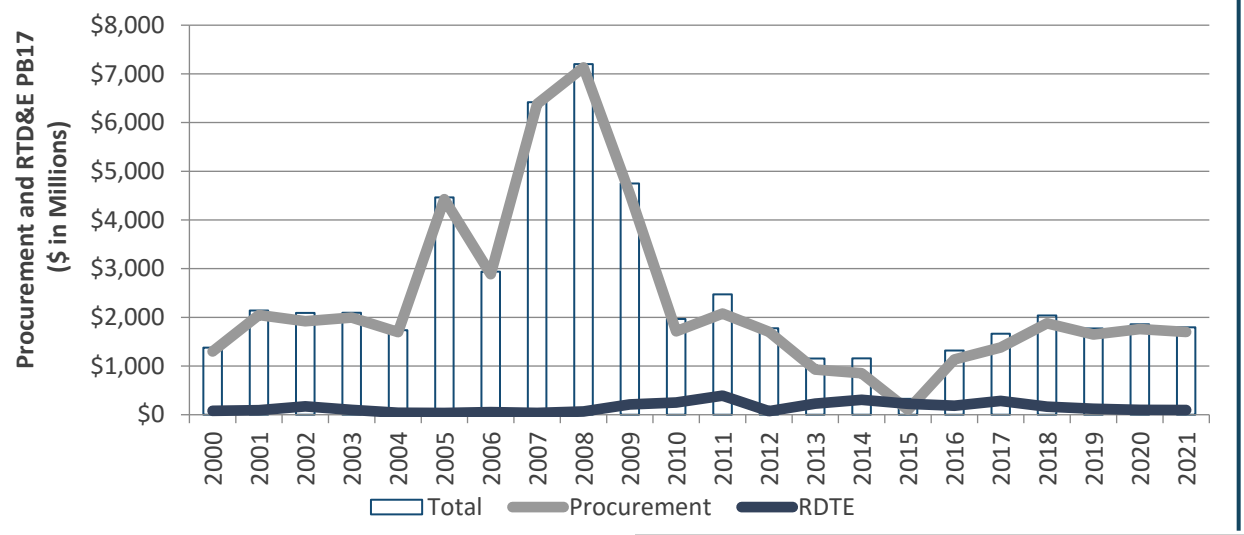
The budget execution activities in Figure 15 highlight the spike in procurement funds during Operation Iraqi Freedom (OIF), Operation Enduring Freedom (OEF), and a future programmed increase for the future as priorities change. Maintenance and recapitalization are not captured in these numbers since they are executed from Operations and Maintenance (O&M) accounts. Systems that did not make it past Milestone B are not assessed to have had a significant impact on the defense industrial base and are therefore excluded from RDT&E data.

RDT&E funding is fairly flat across the two decades. This is expected as RDT&E funds activities that develop new capabilities in existing equipment. Combat Vehicles require a steady development effort to stay ahead of the capabilities of near peer competitors. The Army has demonstrated its commitment to enhancing technology and vehicle capability through engineering change proposals efforts resulting in a focus improving existing capabilities, but the lack of RDT&E funding curtails focus on future innovation.

Procurement funding indicates improvements in capabilities in existing equipment for combat vehicles. Procurement funding peaked in 2008 as the conflicts in Iraq and Afghanistan required that new capabilities be added to existing equipment to increase effectiveness against irregular and adaptive enemies. Future procurement shown consists of upgrades to the Bradley and AMPV, the M113 replacement. They are noteworthy by their lack of any accompanying RDT&E increase to support this procurement.

O&M funds are executed at the lowest possible levels within the Services to allow the largest amount of discretion. It is difficult to determine the amount of O&M funds spent in this effort and much more difficult to determine the amount that enter the industrial base.

Figure 15: Combat Vehicle Funding Profile



Source: Defense Resource Data Warehouse

Industry Suppliers

Table 8 identifies suppliers for combat vehicles.

The defense industrial base has not produced a new armored combat vehicle since the introduction of the M1 tank and the Bradley series of IFVs in the early 1980s

Table 8: Combat Vehicle Suppliers

COMPANY	ARMORED WHEELED	ARMORED TRACKED	INTERNALLY TRANSPORTABLE
BAE	• ACV 1.0 Competitor	• Bradley • AAV • AMPV	
GDLS	• LAV • Stryker	• M1A1 Tank • M1A2 Tank	• ITV • Flyer 60 • Flyer 72
SAIC	• ACV 1.0 Competitor		

Risk Assessment

Overall risk to firms involved in this sector is low. Consolidation of the manufacturing base preceded the general decrease in production, providing a buffer to volatility in demand. Advances in technology and engineering innovation have led to improvements in existing equipment that prolonged vehicle service life and increased capability of legacy vehicles. Foreign military sales (FMS) remain at a high level for combat vehicles and combat support vehicles. In addition to the purchase of equipment, foreign sales also keep demands on the supplier high due to support and maintenance required.

However, the strategy of performing incremental improvements to combat vehicles is reaching its limit. This could place U.S. superiority in combat vehicles at risk. A new start combat vehicle is needed to bring state of the art technologies, materials, employment techniques, weapons, and protection systems to the Warfighter.

Long Term Challenges

Armored Vehicle Design Production, Improvement, and Modification

The military industrial base has not produced a new armored combat vehicle since the introduction of the M1 tank and the Bradley series of IFVs in the early 1980s. The last new start vehicle design to replace the Bradley, the Ground Combat Vehicle (GCV), was cancelled. The alternative chosen by the Army is to replace the aging M113 APC vehicles with a Bradley derivative vehicle (AMPV) and upgrading the Bradley fleet with increased protection.

However, material and technological improvements within the capacity of the fielded vehicle designs are reaching physical limits. The M1 series tanks, Bradley IFV, Stryker, and LAV armored vehicles and the AAV are at or near the limit of improvements in firepower.

The legacy fleet's success at incremental adoption of new technologies on older designs while maintaining and modifying them has allowed the military to defer new starts' long schedules and high costs. However, this may result in a generation of engineers and scientists that lack experience in conceiving, designing, and constructing new, technologically advanced combat vehicles. A new start combat vehicle would permit new engineers to develop the ability to bring SOTA technologies, materials, employment techniques, weapons, and protection systems to the Warfighter.[54]

[54] PEO Ground Combat Systems, "Engineering Skills Assessment," October 9, 2015.

Increasing Material Demand

Multiple simultaneous armored vehicle upgrades and armor enhancement activities coupled with shipbuilding demands could cause a limitation in domestic availability of aluminum armor plate delaying or preventing planned improvements to the Bradley and construction of the AMPV. Aluminum may be the only alternative for improving protection of vehicles that are near their performance limits due to weight.

Competition between the domestic commercial aluminum markets for products including automobiles, as well as increased shipbuilding demand, is requiring some demand to move foreign suppliers. Defense programs are beginning to consider switching to less effective armor plate alloy alternatives to guarantee sufficient domestic supply.

Mitigation Efforts

Armored Vehicle Design

Nothing short of an innovative blank paper design is going to result in any major improvement in U.S. armored combat vehicle firepower or protection. Criticisms of the time from inception to fielding of programs are fair. Radical departures from acquisition regulations such as used in the Mine Resistant Ambush Protected (MRAP) series of vehicles proves that competition and capacity still exists amongst a very responsive industrial base.

In lieu of a newly designed vehicle, DoD has focused on adopting and modifying foreign vehicles that have capabilities that our systems lack. This results in reduced costs and shorter schedules while refreshing engineering skills. The LAV, Stryker, and ACV programs are strong examples. In short, the firepower improvements, increase in troop capacity, and survivability enhancements sought in replacing the Bradley with the GCV are available in vehicles abroad.

Acquisition of modifications of firepower and other technologies to improve foreign capabilities already happen. The German development of the 120mm smoothbore tank main gun led to its adoption in the United States and United Kingdom. As this gun is improved and proofed to a 130mm gun it is a likely target for incorporation in our tank fleet. Adoption Mobile Active Protection Systems is another example of integrating technologies from abroad. Sharing of improvements in design and performance of main gun rounds is also shared as well as the introduction of new ammunition with new purposes.[55]

Real impact to the defense industrial base can be minimized by performing modification work domestically and ultimately moving serial production to the United States. Many of these allied vehicles have U.S. defense industrial base subsidiaries or are subsidiaries of international corporations based in the United States.

[55] Feicjert,A. "Selected Foreign Counterparts of US Army Ground Combat Systems and Implications for Combat Operations and Modernization," Congressional Research Service, January 18, 2017.

FMS demand remains high for proven U.S. equipment and material support as the gold standard. Foreign governments frequently want newly built equipment with the highest level of performance we are willing to export. This factor serves to also keep our armored combat vehicle industrial base viable. The support required to operate and maintain FMS equipment also contributes to keeping our supply chain viable.

Recapitalization of Armor Providers

Only two domestic industrial equipment sets capable of providing monolithic wrought aluminum suitable for armor exist. This portion of the defense industrial base is clearly focused on the commercial aluminum market. The Department is examining alternatives to provide incentives to invest in and maintain the equipment required to meet the aluminum armor demand domestically.

Redevelopment of National Capability to Design Armored Vehicles

Radical technological innovations will eventually result in a new generation of combat vehicle designs. There is a lack of candidate technologies at this time. These technologies may be unrealized or unrecognized now. Any increased funding efforts in basic research into new armored protection concepts, new automotive innovations, and new weapons technology will speed up this realization. Unless deliberate research efforts are made then improvements remain incremental to the limits of the physics of combat vehicles worldwide. Worldwide, current combat vehicles are all slowly approaching parity in lethality, survivability, mobility, and transportability. Right now, the M1A1 tank community is facing a limitation of transportability due to weight and size while initiatives like active protection systems to increase survivability increase weight in a significant way.

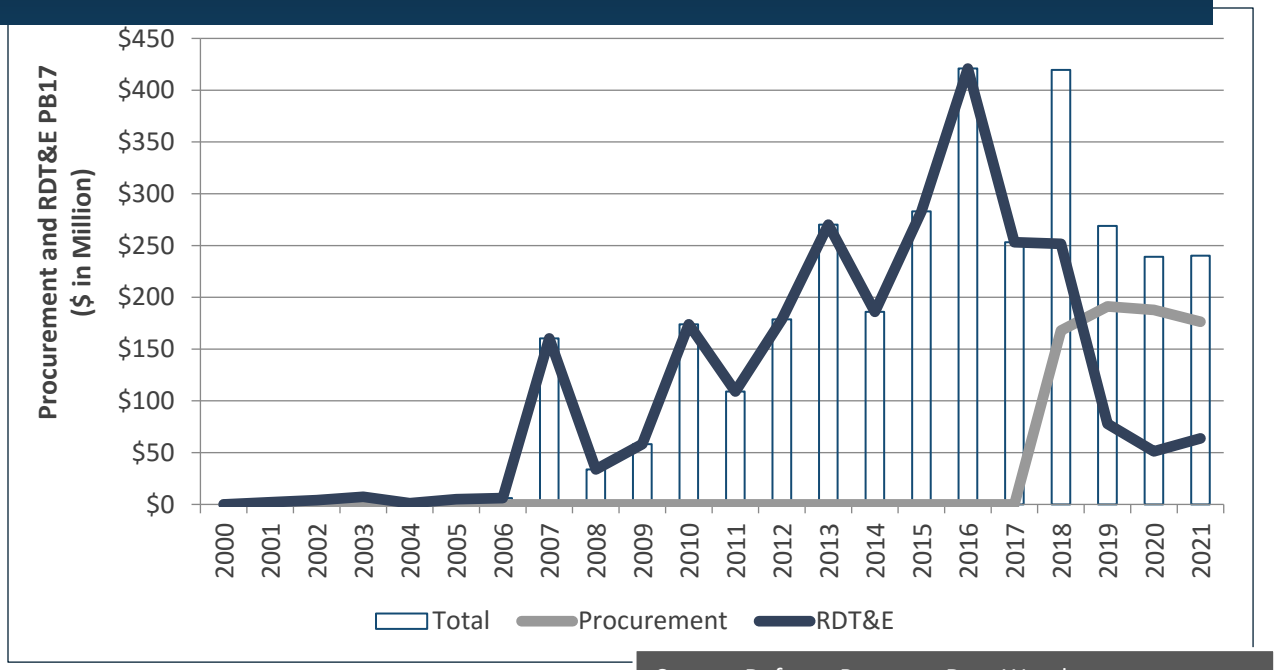
Budget Considerations

Figure 16 illustrates that while procurement and RDT&E dollars are relatively modest, the situation is much different from the other two sectors.

The dominance of RDT&E funding indicates that the biggest effort underway in CS vehicles is designing new parts that replace older design parts to support readiness. The lack of accompanying expenditures in procurement indicates that the RDT&E dollars are resulting in parts and engineering changes that have the same form, fit and function as a previous part or assembly. The parts or assemblies therefore do not require operational test and are purchased and installed using O&M dollars since they do not result in any change in capability. Systems that did not make it past Milestone B are not assessed to have had a significant impact on the defense industrial base and are therefore excluded from RDT&E data.

Procurement is modest in the CS programs indicating that almost no growth is happening in the form of improved capabilities within this sector. The rise in FYDP acquisition funds starting in 2016 represent the procurement of the various ITVs and changes to the capabilities of the legacy MRAP vehicles as they get refined for the future.

Figure 16: Combat Support Vehicle Funding Profile



Source: Defense Resource Data Warehouse

Industry Suppliers

Table 9 identifies suppliers for combat support vehicles.

Table 9: Combat Support Vehicle Supplies

COMPANY	ARMORED WHEELED	ARMORED TRACKED	INTERNALLY TRANSPORTABLE
BAE		• M109 Paladin • AAV	
GDLS	• HIMARS	• MLRS	• EFSS • ITV
Oshkosh	• M-ATV		

Risk Assessment

Overall risk to this industrial base is moderate. New vehicle designs for CS vehicles lags behind the combat vehicle new deigns. The M109 Paladin remains the only self-propelled howitzer in the U.S. inventory and it dates form the 1960's. Self-propelled howitzers are essential to certain types of fast moving types of combat. Rapid movement and armor protection allow these support weapons to be survivable on a battlefield that includes rapid counter battery fire from the enemy.

The M109 Paladin remains viable due to continuous improvement programs, such as M109 Paladin Integrated Management (PIM) that keep the vehicle sub-systems current. However, the design is near or at its limit for range and rate of fire. Both of these performance parameters are critical and improving the M109 in these areas presents a challenge.

The AAV remains the only vehicle that has the ability to operate from the ocean through the surf zone and onto land. The AAV family of vehicles has undergone an extensive series of upgrades to its subsystems to maintain original sea and land performance requirements. Further modifications in crew protection, armament and crew safety have added more weight.

The Combat Support Vehicles manufacturing base needs to be able to provide continuous improvement to programs to keep vehicles current

While the AAV has likely reached its limit for increased capability and performance in every respect, no replacement is in sight. Plans to keep the AAV system performing at current levels are in the FYDP. Enemy combat systems probably exceed the AAV's limit to provide protection to passengers and crew due to design limitations.

The MLRS rocket system replaced the heavy self-propelled artillery systems (200mm and larger) in the U.S. military. Their longer range, longer than even the heavy artillery systems, provided a great improvement in performance and effectiveness. However the U.S. policy against using sub-munition ammunition undercuts the assumptions underlying the choice of relaying on MLRS. The Army only produces and employs unitary warhead rockets. Additionally, the MLRS launcher has been modified to fire the Army Tactical Missile System (ATACMS) missile. Each ATACMS missile displaces four MLRS rockets. All of these factors contribute to a loss of capacity for long range artillery fire in required quantities.

Long Term Challenges

Armored Vehicle Design, Production, Improvement, and Modification

The United States continued reliance on the AAV and foreign use of this vehicle helps its manufacturer and supply chain remain viable. A new vehicle based on a different concept is invariably in the future. Until then the AAV continues to fill this battle field niche.

Like combat vehicles, the CS vehicle defense industrial base lacks any new start programs. The industries involved depend on improvements and modification programs to remain viable as well as FMS sales. As relative performance decreases in comparison with foreign systems then it is expected that FMS demand will shift to better performing systems in the long term.

Increasing Material Demand

Like the combat vehicles, combat support vehicles depend on aluminum for repairs, replacement, modifications, and construct of new vehicles for FMS.

Mitigation Efforts

Armored Vehicle Design

The ACV will supplement the AAV fleet. Two development contracts were awarded to U.S. vendors that are modifying existing vehicles with their foreign partners. The ACV program is progressing rapidly since both vendors are modifying existing vehicles. The ACV will transit seaward and shoreward in a surf zone characterized by a Significant Breaker Height of not more than 1.2 meters (4 feet). U.S. specific modifications and assembly are performed domestically. One design is planned to transition to production for the U.S. manufacturing industrial base.

Management of Future Opportunities

FMS can keep production facilities and supply chains operating as long as the United States is producing competitive equipment and providing superior long term support to the equipment.

Combat Service Support Vehicles

Budget Considerations

Figure 17 illustrates DoD funding for tactical wheeled vehicles over a twenty year period including the projected FYDP. The first rise illustrated is the result of a spike in Department procurement in 2008 of new tactical wheeled vehicle equipment and equipment capability improvements in support of ongoing conflicts. The second rise in procurement funding for tactical wheeled vehicle equipment starting in FY2016 and peaking in FY2020 is largely driven by the JLTV procurement. The rise beginning in the FYDP also includes plans for improving the capability of existing vehicles that started in 2016-2017.

The Army Modernization Plan for tactical wheeled vehicles replaces an estimated third of the HMMWV fleet with JLTV's. The modernization plan does not yet include a specific strategy for maintaining or replacing the legacy HMMWV fleet. Since O&M expenditures are executed at the lowest possible level, the data to evaluate the funding being spent in this area is not readily available. However, in the case of tactical wheeled vehicles, the effort to keep readiness and availability of vehicles returning from overseas is very expensive. One prime contractor, AM General, has focused efforts solely in this area as a result of the JLTV award to Oshkosh. Oshkosh also performs repair and maintenance work on AM General HMMWV's as do the Army's depots. How the competition for maintenance and repair of HMMWV's between Oshkosh, AM General, and the depots is going to impact the defense industrial base remains unknown.

Figure 17: Combat Service Support Vehicle Funding Profile

Source: Defense Resource Data Warehouse

Industry Suppliers

Table 10 identifies suppliers for combat support vehicles.

AM General and Oshkosh are the only two manufacturers providing DoD tactical wheeled vehicles today

Table 10: Combat Service Support Vehicle Suppliers

COMPANY	WHEELED	TRACKED
AM General	• HMMWV	
BAE		• Hercules
Oshkosh	• JLTV • FMTV • FHTV • PLS • LVSR • HEMITT	

Risk Assessment

The overall risk to support of the industries involved in this industrial base is low. The tactical wheeled vehicle industrial base is highly dependent on commercial automotive technology and production capabilities. There has been consolidation of production to essentially two manufacturers of tactical wheeled vehicles with one dominant supplier, Oshkosh, which has the capacity to increase production even with JLTV production beginning.

The business market of keeping the tactical wheeled vehicles fleet ready through repairs, refurbishments and modifications remains open to all competitive and qualified manufacturers. For the next twenty to thirty years, the health and readiness of the relatively modern U.S. tactical wheeled vehicle fleet will be the focus of the competitors in this sector, to include the Army's organic depot capabilities.

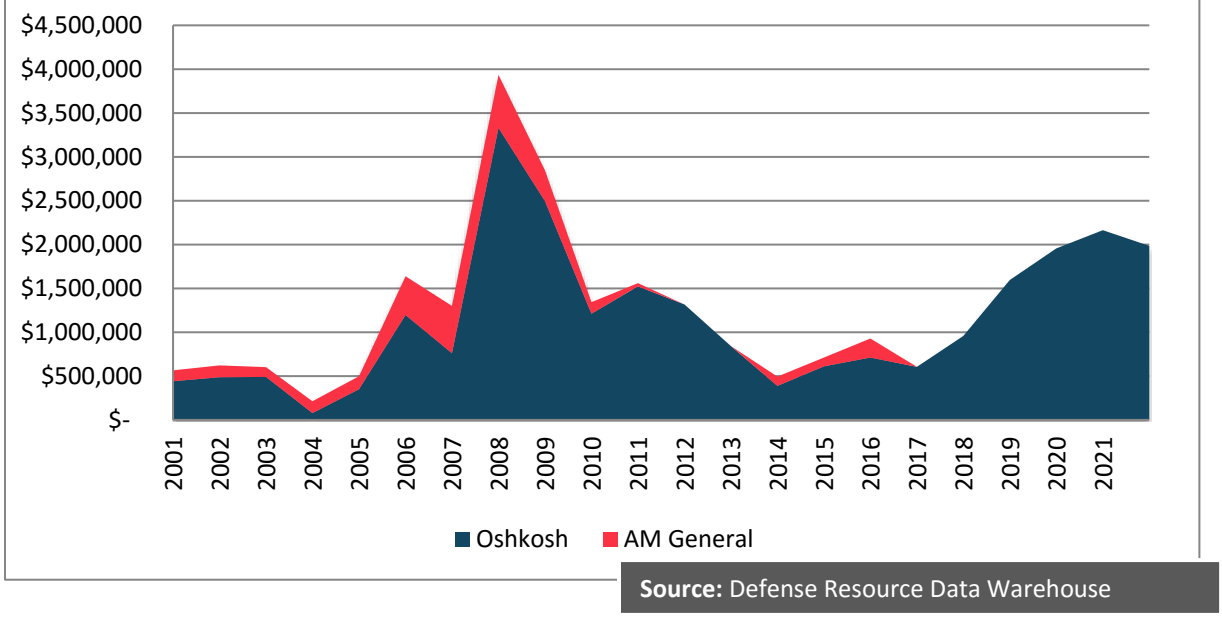
The Combat Service Support Vehicles manufacturing base has the capacity to increase production and is supported by the commercial market

Long Term Challenges

The majority of light, medium, and heavy tactical wheeled vehicles designed for tactical operations and specialty functions are highly centralized with one manufacturer, Oshkosh. This is a result of industry consolidation as well as a continuing series of well-designed and high performing wheeled vehicle programs from Oshkosh that repeatedly have won competitive acquisition competitions. Figure 18 clearly indicates Oshkosh's dominance in the competitive tactical wheeled vehicle industrial sector.

At least one-third of the HMMWV fleet is going to be replaced by the JLTV in the active and reserve forces leaving a significant number of DoD HMMWVs and National Guard HMMWVs needing repair, refurbishment, and modernization over the next twenty years or more. Our foreign partners who continue to procure and field HMMWV fleets will also need to remain ready and viable through industry support throughout the HMMWV lifecycle.

Figure 18: AM General and Oshkosh by DoD Procurement Funding Profile



Source: Defense Resource Data Warehouse

The Department must carefully monitor the engineering and production ability of the tactical wheeled vehicle suppliers to ensure we have a competitive market that can deliver innovative, robust and cost-effective designs for next generation systems and to continuously modernize our current fleet. However, the barriers to entry for this industrial sector are considered relatively low as evidenced by the number of suppliers and supplier teams that competed for the JLTV. The Army evaluated six proposals during the EMD phase and down-selected to two competitors for the low rate initial production and FRP contract. The Department clearly understands the importance of maintaining qualified providers to ensure competition, innovation, and cost effective stability for the next generation of systems.

Mitigation Efforts

FMS

It will become increasingly important for the Department to actively monitor FMS opportunities for repair and refurbishment work. A balance between these manufacturers, as well as depots, must be ensured to prevent any portion of the defense industrial base from leaving the sector.

Management of Future Opportunities

Increasing defense industrial base competitors' opportunities for maintenance and modification of existing ground vehicles is adequate to maintain competitors in the market. The two prime contractors and depots with accompanying supply chains will remain viable, if allowed to participate rather than undercut each other in competition to control the market.

DoD supports maintaining a robust competitive tactical wheeled vehicle sector. The Department has a few competitive opportunities in the future.

- The Army is expected to compete the next FMTV lot.
- The National Guard M997A3 Ambulance Program provides modified HMMWVs for use as ambulances.

Materials Industrial Summary

Access to the basic raw materials (e.g., common metals and alloys as well as more scarce mineral elements and compounds required for producing finished and intermediate products and components) is integral to the U.S. manufacturing base and the Nation's overall economic and national security. Typically, material supply chains rely on considerable international trade, including basic raw material inputs through intermediate and fabricated materials products. In general, globalization results in greater access to lower costs materials. However, it may also create significant dependency on foreign resources, which could lead to a range of actions that distort prices, impact investing in other sources of supply or disrupt supply chains. Examples include foreign export controls and differing approaches by other countries to regulate mining and material processing (e.g., production quotas and permitting). For certain materials, difficulties obtaining the necessary permits and accessing sufficient capital remain impediments to the establishment of robust sources of domestic supply. In materials such as beryllium and titanium, on the other hand, there are industries with established domestic supply chains that are competitive and profitable.

Overall, the requirements of the defense industrial base represent a small percentage of overall U.S. demand for materials such that U.S. consumption and supply chains are most often focused on serving non-defense demands within commercial sectors. Therefore, maintaining a vibrant commercial manufacturing base is essential to the health of the defense industrial base.

The Department closely monitors the materials required by the defense industrial base and their supply chains—especially those materials where there may not be a strong demand impetus from the commercial sector. Of further concern are defense demands that are very dependent on certain materials that are essential (not readily substitutable) and whose supply may be especially fragile and or not otherwise sufficiently available -- especially during a national emergency. In addition, the Department's focus on basic raw materials has increasingly expanded to higher value-added materials and semi-finished manufactured goods (e.g. specialty chemicals, metals, alloys and other advance materials including those used for electronics, composites, energetics and armor material applications). The supply of many of these materials, and especially those specifically qualified for DoD defense applications, are limited to single producer companies (both foreign and domestic).

For purposes of assessing DoD-wide defense industrial base needs for strategic and critical materials, identifying potential material shortfalls, and supporting DoD-wide risk mitigation actions, the Department relies on its National Defense Stockpile (NDS) Program. Strategic and critical materials generally refer to those materials which may not be sufficiently available and deemed to be essential. The NDS Program actively monitors over 100 materials and assesses DoD-wide defense demand and available supply. When U.S. defense demand exceeds supply, shortfalls are estimated. DoD's preferred option for mitigating defense shortfalls is Government acquisition of shortfall materials for stockpiling purposes. In DoD's latest stockpile requirements report to the Congress, the Strategic and Critical Materials 2015 Report on Stockpile Requirements, the Department identified a number of defense shortfall materials and is actively pursuing plans to purchase materials for stockpiling purposes.[56]

Defense demand often represents a very small fraction of overall U.S. demand for most materials assessed by the NDS Program. As such, DoD's use of DPAS—which by law provides DoD access to domestic sources of materials ahead of U.S. civilian demand for national security purposes—readily mitigates defense shortfalls for common raw materials. The Department notes that nearly all of the current defense shortfall materials in the 2015 NDS requirements report represent single foreign sources of supply. In these instances, DPAS is not applicable.

[56] Nearly all of the defense shortfall materials represent value-added engineered materials that are unique and proprietary to single foreign, and in limited cases domestic, sources of supply (e.g., specialty chemicals, alloys, high performance fibers, ceramics and other materials). See classified and business proprietary 2h appendix of the 2015 NDS requirements report to Congress.

In addition to Government stockpiling, the Department has other risk mitigation options available including Title III of the DPA (to incentivize U.S. production of shortfall materials), ManTech (to help increase domestic production competiveness), and security of supply arrangements with foreign countries.

Despite limited capabilities and capacity to produce various rare earth materials, U.S. defense programs are not disrupted nor are shortfalls anticipated

Among the many materials supporting defense weapon systems, the availability of rare earth materials continues to garner considerable attention. Since the Department's initial rare earths report to Congress in 2011,[57] there has been a significant change in the global marketplace. In response to global market concerns about a potential future shortage of rare earths, demand and prices rapidly increased on speculation. Global demand then decreased significantly because of rising prices. Due to a number of factors, global demand subsequently fell dramatically. Available supply then rapidly increased and rare earth prices collapsed.

Gaps remain in the rare earth domestic supply chain. In addition to the 2015 closing of the only active commercial rare earths mining operation in the United States (Molycorp), the United States has limited capabilities and capacity to produce various value-added rare earth containing materials (e.g., separated oxides, metal, alloy and magnet materials) due to unfavorable market conditions overall and a lack of U.S. competitive advantage. Nevertheless, the Department notes that the supply of rare earth materials for U.S. defense acquisition programs is not presently disrupted and future shortfalls are currently not anticipated.

MIBP coordinates with organizations within the Department (e.g., DLA Strategic Materials and the Military Services) as well as the U.S. interagency community (e.g., U.S. Geological Survey, DoC, U.S. Trade Representative, and the White House Office of Science and Technology Policy) to address the issue of strategic and critical materials availability.

This whole-of-Government approach effort seeks to identify materials of concern to national security, assess the ability of the supply chains for these materials to meet U.S. industrial base requirements, and develop strategies to ensure their availability.

[57] USD (AT&L) Interim Report to Congress, "Assessment and Plan for Critical Rare Earth Materials in Defense Applications", August 2011.

Munitions and Missiles Sector Industrial Summary

Industry Overview

The munitions and missile industrial sector is comprised of DoD's 'smart' bombs (e.g., small diameter bomb (SDB)), tactical (cruise, air-to-air, air-to-ground, surface-to-air) missiles, missile defense, and strategic missiles. These will all be referred to in this report as 'missiles.' It also includes 'dumb' bombs (including bombs with added tail kits and guidance (e.g., joint direct attack munition (JDAM)), ammunition, mortars, and tank rounds, etc., but since most/all of the major issues lie within the missile industrial base, dumb bombs, ammunition, mortars, and tank rounds are not specifically addressed in this report beyond this overview section. However, many of the issues listed for missiles are also applicable to other munitions, especially declining procurement numbers, which has led to production line shutdowns and plants that are being closed or consolidated into smaller footprints and smaller capabilities. The munitions and missiles industrial sector is primarily a defense unique industrial sector.

The Department provides the necessary resources to the industrial sector to ramp up production for munitions and missile systems to support Warfighter needs when the country is engaged in conflict and it reduces these resources when the conflict ends. This cycle of ramp-ups followed by declines of demand and production adds significant management challenges to munitions and missile companies and their critical sub-tier suppliers. While all industrial sectors are challenged by rapid changes in DoD demand, this ramping up and down based on global conflicts increases risk for defense unique industrial sectors at the sub-tier supplier level because many do not have the diversity of programs or products from other non-defense markets to support their design and production skills. This risk manifests itself in multiple ways, from the inability to surge production quantities to meet munitions requirements, to key sub-tier suppliers exiting the business when they can no longer remain viable.

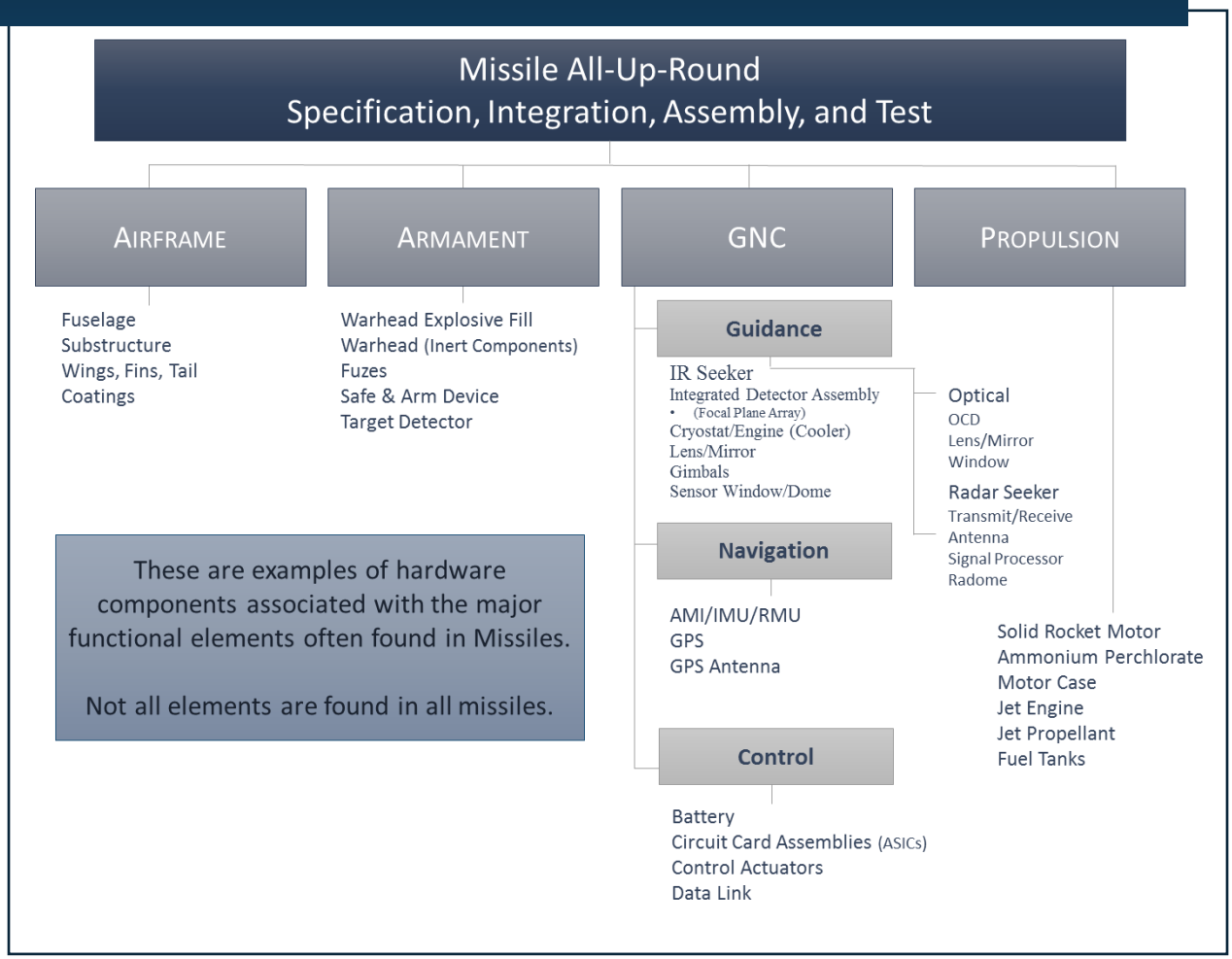
Over the past two decades, there have been no new development programs in the missile sector. All 'new' missile programs have been designed as, or have become, upgrades to existing systems. This sector is also undergoing a decline in procurement; as a result, the design and production skills for critical components within the missile sector industrial base are at risk. The loss of this design and production capability could result in costly delays, unanticipated expense, and a significant impact to many current and future missile programs, damaging the readiness of the Department, and negatively impacting a foundational national defense priority by placing our ballistic missile production capability at risk.

Fortunately, there are two new tactical missile programs that are about to enter development, Advanced Anti-Radiation Guided Missile Extended Range (AARGM-ER) and Long Range Precision Fires (LRPF). If these programs continue, this would provide much needed work to exercise the missile industrial base design skills.

There is also one new strategic missile program, Ground Based Strategic Deterrent (GBSD), the LGM-30G Minute Man III Inter-Continental Ballistic Missile (ICBM) replacement. Numerous demonstration/validation programs have been funded over the past several years, providing some design work to industry, particularly to the large solid rocket motor industrial base, which has not seen any new design work in decades.

The general missile taxonomy shown in Figure 19 breaks the missile into four functional areas: propulsion; armament; airframe; and guidance, navigation, and control (GNC). In the propulsion area, most missiles use a solid rocket motor (SRM). The size of these motors can range from 2.75 inches in diameter to as large as 83 inches for some strategic and ballistic missile defense systems. Some tactical missiles, like the Tactical Tomahawk, use a jet turbine fan engine. The major distinction for the warhead is either nuclear or conventional. Airframes consist of the fuselage, wings, fins, tail, and substructures. Airframe materials for these components range from aluminum to complex composites. The GNC area, in many cases, comprises the most expensive components of the system (mostly missile seekers).

Figure 19: General Missile Subsystem Taxonomy



Budget Considerations

As seen in Figure 20, RDT&E budgets for ballistic missile programs increased from the 2011 to 2017 timeframe, mostly due to the Ground Based Interceptor program and some work on Standard Missile 3 (SM-3) and Patriot Advanced Capability 3 (PAC-3), but are slated to decrease dramatically after that. Budgets for tactical missiles have remained mostly flat, with decreases in the 2013/2014 timeframe. Most recent "new start" missile programs such as the Joint Air-to-Ground Missile (JAGM) have been converted to or designed as slight modifications of existing systems (new seeker for Hellfire in the case of JAGM) versus actual new missile designs. This does not allow the design, development, and integration skills within the tactical missile industrial base, and specifically the SRM industrial base, to be exercised, and limits competitive opportunities.

The skill set necessary to design, develop, prototype and test a new missile is very different from the skill set for producing an existing missile. Most DoD tactical missiles have been produced for many years or even decades, and have reached steady state, limiting opportunities for industry to hone its design capabilities. RDT&E budgets for strategic missiles show an increase, especially in the out years, that is due mostly to the GBSD program.

Figure 21 indicates that procurement budgets for tactical missiles have increased overall. However, funding for tactical missile programs can increase and decrease dramatically as inventory and usage demands change. This creates stress on the tactical missile industrial base, especially on the smaller sub-tier suppliers, who must remain viable in low production environments while remaining ready to ramp up production as needed. Ballistic missile budgets have increased slightly, while strategic missiles remain fairly steady.

Figures 20 and 21: Missile Funding Profiles

Figure 20: Missiles and Munitions RDT&E Funding Profile

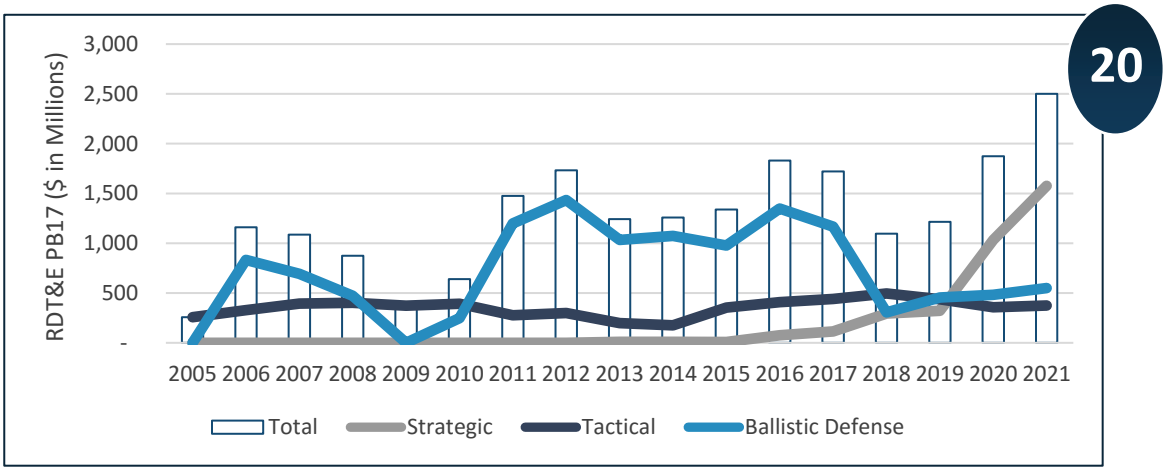
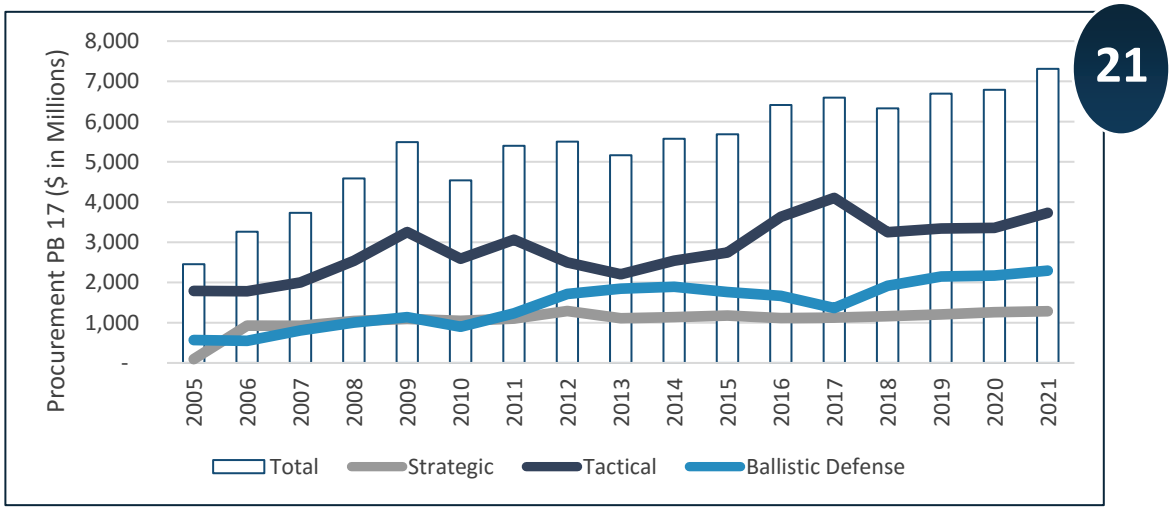


Figure 21: Missiles and Munitions Procurement Funding Profile



Source: Defense Resource Data Warehouse

Funding for tactical missile programs can increase and decrease dramatically as inventory and usage demands change creating stress on the tactical missile industrial base

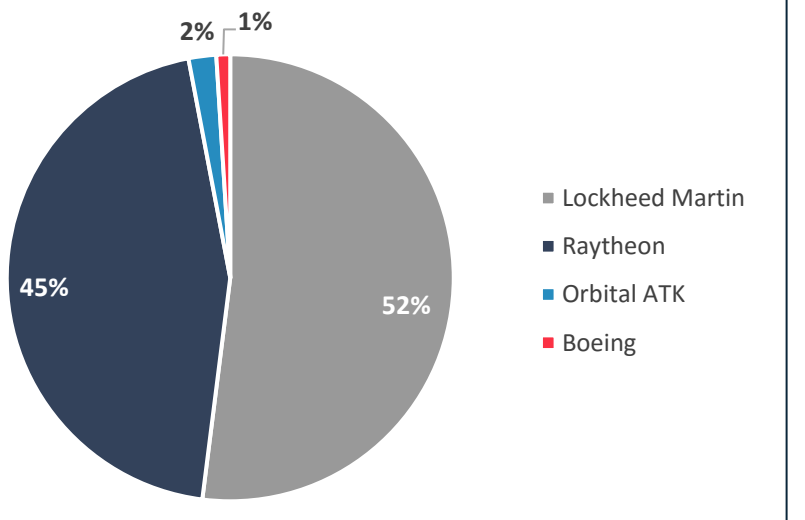
Industry Suppliers

The missile sector experienced significant consolidation after the Cold War resulting in aggressive competition for limited new program opportunities. Within the munitions and missile sector, two prime contractors, Raytheon Missile Systems (a division of Raytheon Company) and Lockheed Martin Corporation, account for roughly 97% of the Department's munitions and missile procurement funding, as indicated in Figure 22. These prime contractors provide a full complement of missile types across the munitions and missiles sector and, for the most part, are able to meet defense unique technical performance requirements. DoD's prime contractors and their associated sub-tier supplier base must align company production capacities with expected DoD budget realities while sustaining the industrial capabilities needed for current and next generation weapon systems.

There are currently only two domestic suppliers for solid rocket motors used in DoD missiles – Orbital ATK (OATK) and Aerojet Rocketdyne (AR). They supply the majority of missile systems, with a foreign supplier making up the balance.

Raytheon Missile Systems and Lockheed Martin Corporation account for roughly 97% of the Department's munitions and missile procurement funding

Figure 22: Missile Procurement Funding Distribution



Source: Defense Resource Data Warehouse

Risk Assessment

The munitions and missile industrial sector is routinely impacted by significant shifts in DoD demand as a result of various factors, but mostly due to the initiation or drawdown of conflicts. Resupply of key munitions used in conflicts, as well as surge requirements for those munitions during conflicts stress the industrial base. Numerous bottle-necks with critical sub-tier suppliers preclude a rapid response to these increases in requirements, causing delays in deliveries and increased cost to the Department. And as the Department draws down from certain overseas operations, it is monitoring the impact of reduced demand on the sub-tier supplier base through continuing assessments of the defense industrial base (including FaC assessments) in close cooperation with the Military Departments and MDA. The Department expects to identify a growing number of industrial capability risk areas as sub-tier suppliers realign and adjust their industrial capacities to DoD budget realities.

In 2013 for example, MIBP performed a FaC assessment of the missile industrial sector. MIBP collaborated with the Fuze IPT and the Critical Energetics Material Working Group (CEMWG), among others for valuable industry and product information in their respective industrial sectors. Mitigation efforts for solid rocket motors, thermal batteries, and fuzes were supported by the FaC analysis and are discussed later in the report. The health of sub-tier suppliers in defense unique fields is a serious and valid concern. Important defense unique sub-tier components in the missile industrial segment that continually face excess capacity challenges include thermal batteries, solid rocket motors, fuzes, jet engines, inertial measurement units (IMUs), GPS receivers, seekers, and warheads. The suppliers that provide these components are used on multiple programs, and some of these components require 12 months or more to manufacture. Some of these sub-tier supplier products have broader utility and commercial applications that provide a more reliable and stable market base to sustain industrial design and production capabilities such as the IMUs, GPS receivers, and seeker product sectors, while others are more unique to the missile industrial sector. MIBP continues to monitor the health of the sub-tier suppliers identified in the FaC assessment. The assessment confirmed previously known industrial base challenges. These challenges fall into two broad categories; (1) sustaining our design and engineering teams and (2) sustaining the sub-tier supplier base.

The following missile industrial base issues continue to be identified as the areas with the highest risk.

Solid Rocket Motors

SRMs are predominantly defense unique items. SRM providers and their sub-tier suppliers face demand uncertainty because missiles are often used as bill-payers in fiscally constrained environments. The challenge is the high cost for reconstitution should the SRM industry encounter a significant production gap.

This is particularly true in the large (over 40-inch diameter) segment of the market. NASA's retirement of the Space Shuttle and the transition of the Constellation program to the Space Launch System have resulted in significant under-utilization of existing capacity in this segment.

Maintaining a healthy and competitive SRM industrial base is also of concern to the Department. SRMs for tactical missiles are produced in a nearly even split between the two domestic suppliers, OATK and AR. However, in the very near future all the large SRMs for strategic missiles and space launch will be produced by OATK. AR has managed to maintain their large SRM capability with production of the boosters for the United Launch Alliance (ULA) Atlas V and Delta IV space launch vehicles, and small development investments from the GBSD program. But ULA has chosen OATK's boosters to replace AR's on Atlas and future launch vehicles, leaving AR with no large SRM production. If AR is not chosen to produce at least one of the 3 SRM stages for GBSD, they may choose to exit the large SRM business, leaving only one supplier.

Thermal Batteries

All DoD missiles and Precision Guided Munitions use thermal batteries. Thermal batteries are predominantly defense unique items and the domestic thermal battery industry has historically been dominated by one company with little participation by other firms, mostly due to low production quantities. The other domestic companies that produce thermal batteries constitute less than 20% of the DoD thermal battery market. The dependency on a dominant supplier of thermal batteries makes this industry at risk. Investments in improvements to battery technologies are also lacking due to low production quantities and profit margins. Many of these items are made by hand and have repeatability and quality issues.

Fuzes

Fuzes are defense unique items – they are used on all munitions and missile programs. Continued improvements in guided systems significantly reduced the quantity of fuzes required for our current and future systems. This has contributed to an excess capacity in the fuzes sector. Excess capacity limits manufacturers from being cost competitive and limits investment in improvements to fuze technologies, including sustaining a viable design engineering cadre. The U.S. currently has three full-capability fuze design manufacturing suppliers. The fuze prime contractors are aggressively managing several defense unique sub-tier component areas, such as electronic energy devices (e.g., bellows actuators), liquid reserve batteries, and certain obsolete electronic components to ensure their ability to design and produce fuzes in the future.

Long Term Challenges

Most current missile development activity consists of modifications to existing missile systems, such as the Rolling Airframe Missile (RAM) Blk 2, PAC-3 Missile System Enhancement (MSE), and AARGM-ER. Most of the research and development funding in the munitions and missile sector is associated with legacy program upgrades or modifications, which limit competitive opportunities. The limited number of new missile development programs inhibits the Department's ability to fully exercise the industrial capabilities necessary—from design concept, system development, and production—to meet current and future national security needs.

The Long-Range Anti-Ship Missile (LRASM) and the JAGM were previously the only "new" missile development programs in competition. However, these too follow the same model. After being restructured as a technology development program, the JAGM program now reflects a front-end modernization for the Hellfire missile. While LRASM leverages a DARPA demonstration project to integrate significant modification to legacy JASSM-ER, it does not rise to the level of a major new program starting from basic technology development. Neither program has significant design work, and have no SRM design requirements. AARGM-ER is also an upgrade to a current system, but will include a new SRM. The only true new missile system will be the LRPF, which will require a completely new design.

The Department remains concerned that the design engineering capabilities needed for tactical and strategic missile systems may not be readily available in the absence of a long-term demand signal. An indication of the concern for strategic missile design engineering capabilities can be seen as the newest DoD strategic missile in the U.S. inventory, the Trident D5 missile, began its development in 1978. This has the potential to affect the GBSD development program, which is already on a short time-line. The Air Force has been funding some early demonstration/validation work for GBSD to help mitigate this. Table 11 provides a sampling of U.S. missile programs, their dates of development, and their current program variants. It is worth noting that with the exception of RAM Blk 2, the last missile development program was JASSM, which began over two decades ago. The one before that was AMRAAM, which was nearly 40 years ago. The RAM Blk 2 SRM contains mostly legacy designs and technology, so while it is technically a new SRM, it has not done much to advance the design skills and capabilities of the SRM IB.

A contraction in the munitions and missile development and procurement market has created a thinning of expertise in defense unique technologies in both the contractor and Federal government workforces. Declining munitions and missiles R&D funding, coupled with limited competitive opportunities projected in the near-term for new munitions and missile systems, makes it difficult for the missile sector industry to attract and retain a workforce with the industrial capabilities to design, develop, and produce future missile systems that will meet national security requirements.

Table 11: History of DoD's Missile Development Programs

Missile Program	Development Start	Production or Delivery Start	Current Variant
AIM-9 Sidewinder	1946	1953	AIM-9X
AMRAAM	1979	1988	AIM-120D
Hellfire	1974	1982	AGM-114R
TOW	1963	1968	TOW-2B
Patriot	1969	1981	PAC-3 MSE
Standard Missile	1963	1967	SM-6
Trident II D5	1978	1987	D5
Minuteman III (LGM-30G)	1964	1968	MM III
Tomahawk	1970's	1983	Block IV
JASSM	1995	2001	JASSM-ER
RAM	2006	2014	Blk 2

Critical Issues

MIBP collaborated with the OSD-chartered CEMWG to assess missile energetic materials. Many of these materials have single or sole source suppliers, many of which are foreign. Examples of domestic and foreign source supplier issues are highlighted below, and various mitigation efforts are discussed in the next section.

Hydroxyl-terminated Polybutadiene (HTPB)

HTPB is a polymer which is a key component in the SRM for a majority of DoD missile systems. The current domestic sole source supplier of HTPB for propulsion applications is Total, a French company. There have been a number of deficiencies in the material quality and repeatability identified by users, including variability and inconsistency from lot-to-lot, which has resulted in the material being unusable in certain missile systems. Therefore, in addition to the risk from a sole source, foreign owned supplier, there is risk of unavailability of this material for key DoD weapons systems.

Ammonium Perchlorate (AP)

The DoD must find a long-term solution to mitigate the high cost and schedule risk to our missile programs resulting from the fragility of our sole domestic supplier for AP. Numerous studies and reports to Congress have identified the Department's supplier, American Pacific (AMPAC), as a critical sub-tier supplier. AMPAC produced AP is used in virtually all of the DoD's missile programs. However, due to decreasing demand, AMPAC is currently operating at 10 to 15% of facility capacity, resulting in large overhead expenses distributed among a small volume of customers. To date, there has been large increases to the price per pound of AP and projections are for this to continue to increase as demand decreases.

Dimeryl-di-isocyante (DDI)

DDI is a critical propellant ingredient, used as a curing agent in many DoD missile systems (e.g. AMRAAM, AIM-9X, GMLRS, Patriot, and Trident D5). BASF, the sole U.S. source supplier of this material informed the missile and rocket motor industry that it would no longer provide DDI due to an unfavorable business case, leaving the DoD with no qualified source.

Dechlorane Plus 25

Nearly all DoD missile systems use Dechlorane as a component in the insulation for their solid rocket motors. There is no domestic supplier for this material; the sole source is Occidental Chemical in Belgium. Even more concerning is that the pre-cursor to make Dechlorane came from China. The Chinese source can no longer produce that pre-cursor and so there is now no source for Dechlorane in the world.

Cyclotrimethylene trinitramine (RDX)

RDX is a high explosive used in many DoD weapons systems, including bombs, warheads, and some missile systems. Re-supply and surge requirements for certain munitions have highlighted a capacity shortfall for RDX manufacture, which will delay delivery of those munitions.

Working groups involving different programs are addressing and managing these critical issues to ensure a coordinated approach to be more efficient and assume less cost for the Department

Material Obsolescence

Material obsolescence has become a critical issue for the missiles and munition sector. A recent study of 35 'key' munitions in production found that the industrial base is dominated by single/sole source suppliers. For second tier suppliers there were 253 critical components (121 suppliers), and 98% of them were single/sole source, and for third tier suppliers there were 131 critical components (73 suppliers) and 98% were also single/sole source. With the decline in usage of materials that make up these weapons systems, some companies have stopped making these materials, mostly due to unfavorable business cases to continue production. In most cases there is not a viable alternative drop-in replacement, so there is cost to find or develop a new material. Even if there a replacement, the requalification costs for the new materials can be prohibitive, especially for larger missile systems. DDI and Dechlorane 25 are just two examples of the myriad materials that have become obsolete recently. This issue is also not limited to legacy systems, as materials can and do become obsolete even during development programs. Most programs do not plan or budget for obsolescence, and the Department and industry do not have a coordinated mitigation approach for this issue. Programs and companies operate independently, which leads to the Services and Agencies paying to solve the same issue(s) multiple times. A more coordinated approach would be more efficient and less costly to the Department.

Mitigation Efforts

Activities by the Services and MDA that potentially help mitigate issues in the missile sector are listed below.

The Department of the Navy

The Department of the Navy (DoN) is implementing a Cruise Missile Strategy, as follows:

1. Sustainment of Tomahawk Land Attack Block III and Tactical Tomahawk (TACTOM) Block IV weapons through their anticipated service lives.
2. Integration of modernization and obsolescence upgrades to BLK IV TACTOM weapons. On October 3, 2016, the Assistant Secretary of the Navy for Research, Development and Acquisition (ASN(RDA)) approved a Maritime Strike Tomahawk (MST) Rapid Deployment Capability (RDC) to provide TACTOM with an anti-surface warfare capability. Additional anti-access/area-denial navigation and communications upgrades will be integrated into TACTOM during a Fiscal Year 2019 mid-life recertification program which also adds 15-years of increased service life to all BLK IV TACTOM weapon all-up-rounds.

3. Fielding of the Long Range Anti-Ship Missile (LRASM) as the Offensive Anti-Surface Warfare (OASuW)/Increment 1 material solution to address near to mid-term anti-surface warfare threats.
4. Development of follow-on Next Generation Strike Capability (NGSC) weapons to address future threats in time to replace or update legacy weapons, while bringing next generation technologies into the Navy's conventional standoff strike capabilities. NGSC will address the Next Generation Land Attack Weapon (NGLAW) to initially complement, and then replace, current land-attack cruise missile weapon systems and OASuW/Increment 2 to counter long-term anti-surface warfare threats. On November 28, 2016, the Under Secretary of Defense for Acquisition, Technology and Logistics approved the Department of the Navy's request for NGLAW to enter the Milestone-A phase and initiate the formal Analysis of Alternatives. With FY2017 Congressional approval, the DoN plans to complete OASuW/Increment II acquisition planning.

Additionally, ship self-defense weapon systems are migrating to integrate active seeker capabilities, leveraging common-guidance section architecture from the joint AMRAAM C-7 into SM-6/Block 1 and the Evolved Sea-Sparrow Missile (ESSM)/Block 2. This family of missile systems approach leverages previous design efforts to reduce overall weapon system development costs, applies common technologies to new/different warfighting mission areas, and decreases weapon unit costs via more efficient production quantities.

Air Force

The Air Force is beginning early RDT&E efforts for the AGM-86B Air-Launch Cruise Missile replacement, the Long Range Standoff Weapon.

Missile Defense Agency

MDA conducted market research to determine industry capability for providing technical support for all stages of Government Furnished Property (GFP) rocket motors including Trident I (C4), CASTOR IVA/IVB, Orion, and Orbus 1/1A. The performer would be responsible for providing technical support for motor refurbishment, flight certification, safe handling, transportation, propulsion, propellant/motor/component testing, propellant sensitivity studies, aging assessment, storage, demilitarization and other technical support as needed. MDA is currently conducting final market research to support its acquisition strategy development.

MDA also conducted market research to determine industry capability to provide Medium Range Ballistic Missile (MRBM) T3c2 All Up Round targets in support of BMDS flight tests activities. The MRBM T3c2 target requirement includes the design and development of the complete target system, including production equipment; logistics, associated support equipment, system engineering and analysis, and mission operations. MDA determined that sufficient capability existed in industry, issued an RFP, and is currently assessing three responses.

IBAS

During FY2016, MIBP led activities to develop, plan, and execute several IBAS projects intended to mitigate missile sector issues.

Thermal Batteries

In 2016, work continued on three IBAS projects for thermal battery technical improvements in battery materials and shelf life that will lower minimum sustaining rates: improved material composition that will provide additional domestic suppliers, characterization of Thermal Battery shelf-life model to enhance production quality and sustainment (reducing costs and industrial base burden), and improved thin film production to broaden and improve the market.

Fuzes

Without intervention, loss of industry design and production expertise is expected for Electronic Safe and Arm Device (ESAD)-based fuzes. ESADs are most commonly used in missile fuzing, but have applicability to some of the Department's most critical gun-fired and air-delivered munitions as well. To improve the industrial base capability, IBAS is funding ESAD design projects for cost reduction and commonality across multiple missile and munition end-products. Phase I was initiated by contracting with three different suppliers to exercise their engineering capability, including the use of sub-tier suppliers and component technology, to develop lower cost, common architecture ESAD designs. These three suppliers form the critical core of the U.S. Industrial Base for fuzes overall. Phase II is planned for award in FY2017. In this phase, the work from Phase I will then be applied against a post Milestone C munition which can benefit the most from an upgraded fuze capability. Additionally, ESAD component technology awards will be made to both advance the capability of some existing vendors as well as to expand the subtier supplier base.

HTPB

The Army funded a Phase II Small Business Innovation Research (SBIR) project to establish a second source for this material. IBAS funding is used to manufacture more production scale batches for reliability and repeatability testing, and to test the new HTPB in a rocket propellant formulation. The Army is also funding part of the propellant testing and qualification.

AP

MIBP initiated a study, with support from the Army and Navy, to address this critical need. The objective of the study was to explore mitigation alternatives that have the potential to reduce the ammonium perchlorate cost and supply risks for DoD. This included identifying approaches to reduce the capacity in the existing facility and analyzing cost/schedule for development of a new right-sized facility. Reducing the re-qualification cost burden for DoD weapons systems that experience an ingredient change was also addressed. Results of the study were not as expected.

There is not a significant AP supply risk and AP production capacity is unlikely to leave the U.S.market. DoD is paying a premium for this material; without commercial market forces to keep prices down, the sole source is charging higher than a 'fair market value' for this material. The Department is pursuing an alternative acquisition strategy for this material that will reduce cost.

DDI

MIBP worked with BASF to help them understand the importance of this item to DoD's weapons systems – coordinating with the Services and industry to identify usage data to help BASF with their business case analysis. BASF agreed to additional production campaigns and continued production of BASF material (albeit with a different process).

Dechlorane Plus 25

The Department and industry are working to find a replacement material. MIBP is driving a more coordinated approach for this effort, establishing a 'Dechlorane Working Group' to ensure that all the Services and programs that use this material are communicating with each other on government and industry mitigation activities, and leveraging efforts to arrive at a more efficient and cost effective solution. This is the beginning of what could serve as a model for mitigating material obsolescence in the future.

RDX

The Department is exploring ways to increase capacity for this material to meet current and future demand, and to allow for the ability to surge capacity if required.

Space Sector Industrial Summary

Industry Overview

The U.S. space industrial base continues to trend in a positive direction, but growth has slowed from previous years compared to non-U.S. government space spending. The space sector is primarily driven by the commercial (both foreign and domestic) market and includes satellites, launch services, ground systems, satellite components and subsystems, networks, engineering services, payloads, propulsion, and electronics. Reliance on the commercial market provides many benefits to DoD including sources of new technology, but also imposes sources of vulnerability. Potential sources of vulnerability include:

- As the space industry globalizes, companies continue to outsource certain capabilities that are produced more economically abroad;
- Budget declines or program cancellations force companies to reduce R&D spending, eliminate product lines, or go bankrupt;
- Industry shifts its product focus away from defense to commercial products where it can obtain better returns on invested capital;
- Environmental restrictions may prohibit production; and
- Commercial viability may be dependent on foreign markets and requires access to competitive financial backing to compete for sales.

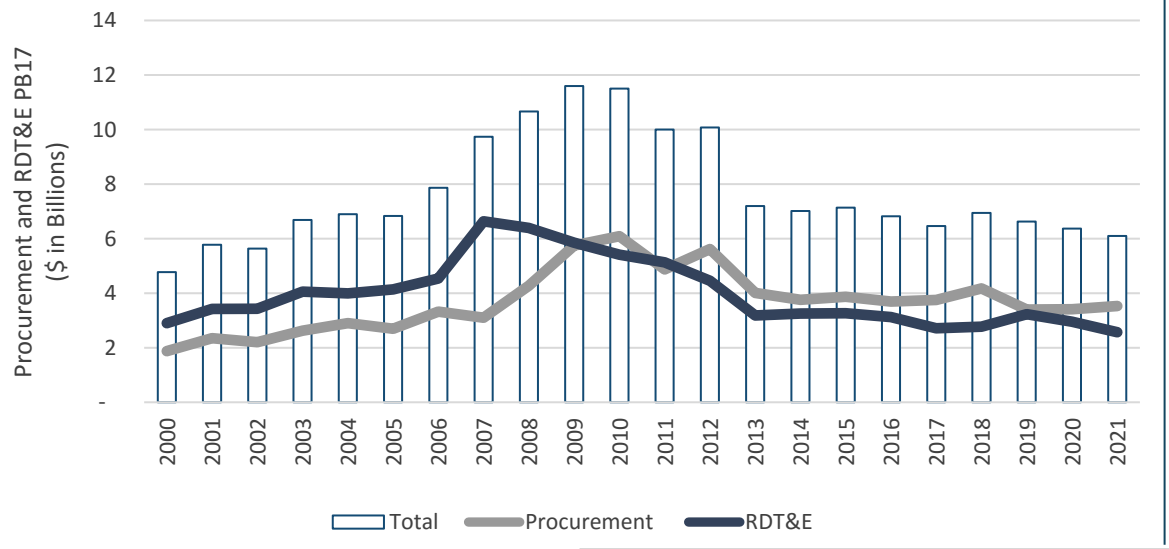
Because of these constraints, the Department must remain vigilant to maintain critical capabilities that are specialized for military applications. This is particularly true for DoD space applications, which typically require cutting-edge technology and stringent requirements but often have very low production quantities when compared with commercial products.

Budget Considerations

As shown in Figure 23, DoD Space program total funding, including RDT&E and procurement funds, was lower in 2016 than at any time since FY 2002 (when comparing total budget in BY 2015 constant year dollars). This includes a downward trend since FY 2008, with total funding being reduced 36.0% between the PB08 and PB16 budgets, including RDT&E down 51.1% and procurement down 13.5% over the same time frame.

While this is in contrast to the overall space economy, which has continued to grow over the past several years, it is indicative of the growing reliance on the commercial sector for continued investment in RDT&E for technology innovation and dual use sales vice DoD investment. Declines in DoD space funding, especially RDT&E funding, could further endanger critical capabilities needed to satisfy current and future program requirements. This finding is consistent with the results of the DoC-led Space Deep Dive study, in which over 10% of the 3,585 space suppliers surveyed (438 vendors) indicated a potential loss of viability or solvency as a result of sudden decreases in space-related demand.

Figure 23: Space Funding Profile



Source: Defense Resource Data Warehouse

Risk Assessment

Stress in the lower tiers of the space industrial base remains for critical components utilized across multiple National Security Space (NSS) satellite and launch systems. Current reliance and increasing competition from foreign sources, as well as domestic supplier fragility derived from the typically low volume demand for components capable of meeting DoD unique requirements and qualifications have placed key capabilities at risk. Establishment and maintenance of trusted, domestic sources remains vital to mitigation of these risks to retain technological superiority, manufacturing capability, and skills which might otherwise be lost.

Recurring assessments across the DoD have confirmed existing issues and identified additional issues requiring elevation resulting from DoD and IC-unique capabilities with no commercial analog or specialized requirements.

Building upon the 2013 DMAG decision to establish the Space Industrial Base Capability Investment Program (SIBCIP),[58] and subsequent approval of $28M from the 2014 DMAG, FY 2016 marked the first year of execution against the 10 highest priority interagency at-risk capabilities identified. Each of these at-risk capabilities were assessed by the SIBWG[59] for uniqueness to government applications; impacts to programs of record; urgency; lack of alternative designs or sources; cost or time to reconstitute the capability if lost; applicability to multiple NSS agencies; and cost/benefit ratio. A 2015 DMAG decision (funded by MIBP, NRO, MDA, Air Force), in coordination with and review by the Defense Space Council (DSC), provided an additional $105M from FY 2017-2021 for mitigation risks associated with these capabilities.

Per the NSS Space Industrial Base Risk Management Program Memorandum of Agreement to maintain a portfolio of issues, the Principal DoD Space Advisor staff, along with MIBP and in coordination with stakeholders, Air Force, MDA, NRO, and NASA, refreshed its integrated-Critical Capabilities List in 2016, identifying several additional at-risk capabilities which it recommends for planning of elevation and mitigation activities.

Establishment and maintenance of trusted, domestic sources remains vital to mitigation of risks in the space industrial base

[58] The Space Industrial Base Capability Investment Program (SIBCIP) funds a systematic, sector-wide, interagency approach to identify, assess and mitigate risk in the space industrial base.

[59] The Space Industrial Base Working Group (SIBWG) is committed to fostering a National Security Space (NSS) IB perspective on critical space industrial base capabilities and fragile suppliers. Managed under the leadership of OUSD(AT&L) Manufacturing and Industrial Base Policy (MIBP) and Principal DoD Space Advisor Staff (PDSAS) with support from the NSS community, to promote management and procurement practices within the DoD and the Intelligence Community (IC) that ensure long-term stable sources for critical industrial capabilities required to meet the missions of the NSS community, to include current and future NSS space and missile programs.

Long Term Challenges

Previously executed "block buys" of systems, such as Evolved Expendable Launch Vehicle (EELV), Space Based Infrared System (SBIRS), Wideband Global SATCOM System (WGS), GPS III, and Advanced Extremely High Frequency (AEHF), continue to provide desired long-term stability across the vast majority of sub-tier providers supporting these programs. However, once sufficient manufacturing and technology readiness levels are established or component bulk buys are completed, some key design teams and skills remain at risk.

Continued investment in advanced technology node is critical to prepare for program adoption by next generation spacecraft. Investment by individual programs tends to result in program specific architectures, and cross cutting reviews of anticipated technology requirements must still be conducted to maximize investment across space programs.

In areas where commercial demand is insufficient or DoD unique components exist, hard-to-reconstitute manufacturing processes must be maintained or improved to sustain efficiency and to avoid schedule and cost impacts associated with re-establishment. Additionally, DoD must weigh improving cost competitive access to foreign suppliers for critical space components against the vulnerability of relying on non-domestic sources. Protecting the integrity of foreign-produced components requires proactive planning of secure engineering designs and architectures, supply chain risk management practices, software and hardware assurance activities, and anti-tamper techniques.

Mitigation Efforts

The Department continues to synergize implementation of SIB risk mitigation efforts, consistent with Titles 10 and 50 of U.S.C., which require inter-agency collaboration in industrial and supply base risk assessments and mitigations. The SIBWG is addressing these common requirements and challenges by leveraging technical expertise and cooperative funding to mitigate these risks in coordination with industry partners and investment. In addition, there is a coordinated strategy among OSD, AF, NRO, MDA, NASA and other agencies to maximize funding levels and to reduce duplication and other inefficiencies in the planned program executions for the FY2016–2021 period.

Key at-risk areas with coordinated mitigation include:

- Radiation hardened advanced technology nodes and components;
- Aerospace structures;
- Infrared detectors;
- Photovoltaics; and
- Attitude determination and control systems.

Shipbuilding Sector Industrial Summary

Industry Overview

The shipbuilding sector remained stable during the FY2016. The Navy shipbuilding industrial base delivered eight ships throughout the year: one destroyer (DDG1000), one amphibious transport dock ship (LPD 26), two littoral combat ships (LCS 7 and 8), two expeditionary fast transport ships (EPF 6 and 7), one oceanographic research ship (AGOR 8), and one oceanographic survey ship (AGS 66).

In FY 2016, the Navy used a limited competition acquisition strategy for the LHA8 and T-AO 205 detail design and construction (DD&C) contracts in order to maintain competition while sustaining critical areas of the shipbuilding industrial base. NASSCO was awarded a contract for DD&C of six T-AO 205 Class Fleet Replenishment Oilers. Ingalls was awarded a contract for LHA 8 planning, advance engineering, and procurement of long lead time material with options for DD&C. Both shipyard contracts include options for the LX(R) Amphibious Ship Replacement. In FY2016, the Naval Sea Systems Command awarded contracts to four shipyards to begin the Fleet Ocean Tug design.

Table 12: Future Navy Shipbuilding Programs (Based on FY2017 Procurement Plan)

PROGRAM	TYPE OF SHIP	EXPECTED CONTRACT AWARD YEAR
Fleet Ocean Tug (T-ATS, formerly known as T-ATF(X))	Command and Support Vessel	2017
Dock Landing Ship (LSD) 41/49 Class Replacement (LX-(R))	Amphibious Warfare	2020

According to the 2017 FYDP shipbuilding plan, the Navy is planning to build 38 ships during the next five years. The Navy will continue using acquisition strategies that allow them to sustain competition and increase efficiency while supporting the shipbuilding industrial sector. Future programs are included in Table 12.

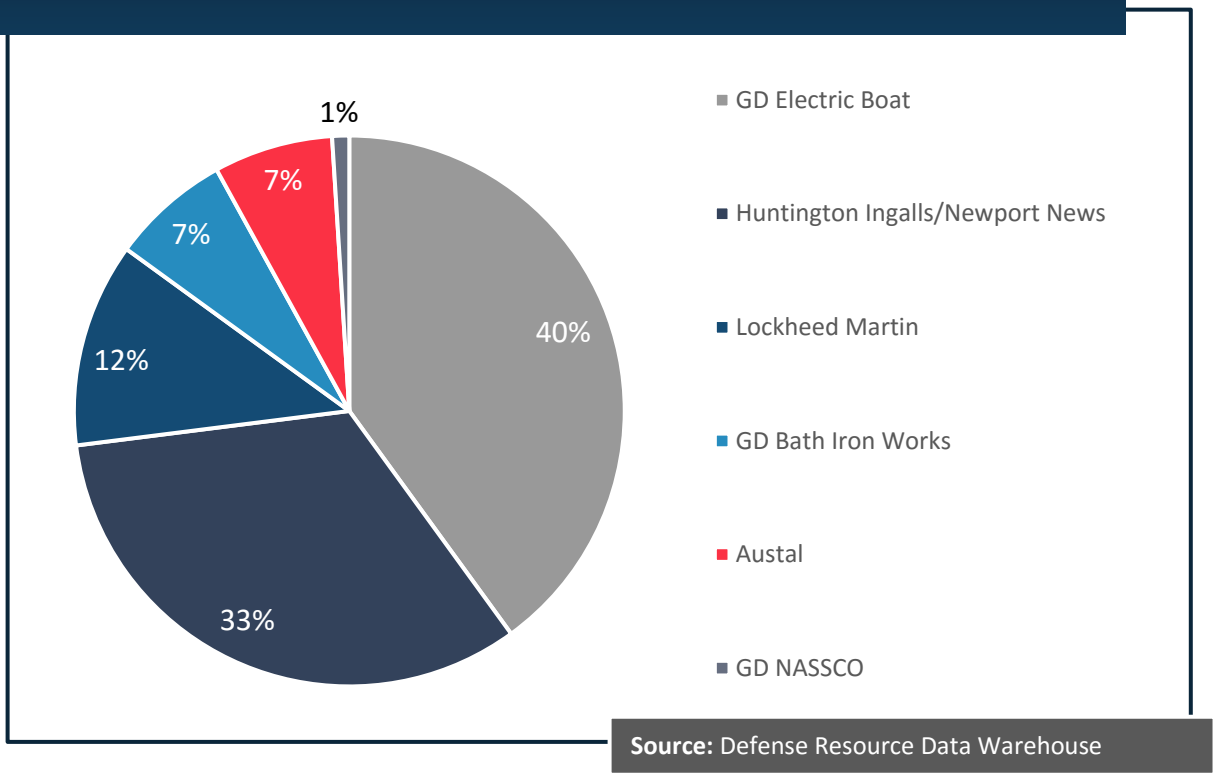
The shipbuilding defense industrial base consists primarily of seven shipyards owned by four companies and their suppliers. The shipyards and locations are identified in Figure 24. The defense industrial base for shipbuilding is segmented by ship type: aircraft carriers, submarines, surface combatants, amphibious warfare, combat logistics force, and command and support vessels.

Figure 24: Primary U.S. Shipyards (Constructing Ships for the Department of Navy)

Budget Considerations

The U.S. shipbuilding industrial base depends on DoD business to sustain critical design and manufacturing skills as well as to maintain their current infrastructure. According to the Federal Procurement Data System Next Generation, the DoN awarded approximately $12.8 billion in shipbuilding procurement contracts in 2016. Figure 25 provides the percentage of participation of the primary shipyards in contracts awarded.[60] Figure 26 illustrates DoD's budget trends in the shipbuilding sector. Shipbuilding procurement funds are expected to continue increasing during the next five years. Funds for RDT&E remained stable when compared to the FY2016 projections. The reduction in RDT&E funds in FY2020 is mostly caused by the Ohio Replacement transition from the development phase to the production phase.

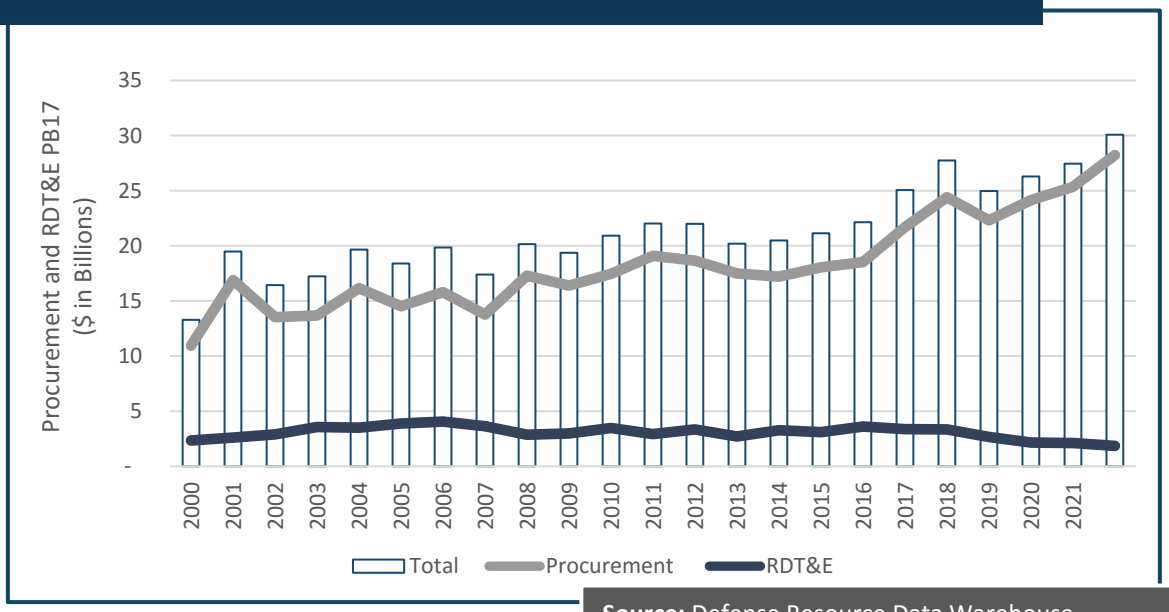
Figure 25: Percent of 2016 Navy Shipbuilding Contracts (by Main Shipyards)



Source: Defense Resource Data Warehouse

[60] Primary is defined as yards that regularly participate in US Navy New Construction programs. Data excludes VT Halter Marine that delivered the AGS-66 and Dakota Creek Inc. that delivered the AGOR-28 in FY-2016. These ships are relatively simple often built to commercial standards. These yards occasionally build auxiliary ships for the US Navy and are not dependent on US Navy new construction or repair contracts.

Figure 26: Shipbuilding Funding Profile



Source: Defense Resource Data Warehouse

Industry Suppliers

The shipyards engaged in naval construction in the United States are identified in Table 13.

Risk Assessment

The combination of new Navy and other Government agencies procurement and maintenance programs combined with commercial ship construction will help support the shipbuilding sector. However, reduced procurements and/or delayed contract awards may negatively impact the workload at the shipyards and, in some cases, disrupt production.

Given the dependence of the shipbuilding sector on defense contracts to maintain a skilled workforce and infrastructure, reductions in quantity and/or fleet composition may threaten the viability of some of the shipyards and their suppliers; therefore, reducing potential benefits achieved from competition in this market.

The combination of new Navy and other Government agencies procurement and maintenance programs combined with commercial ship construction helps support the shipbuilding sector

Table 13: Shipyards Engaged in U.S. Naval Construction

SHIPBUILDER	SHIPYARD	TYPE OF SHIP	PROGRAM
General Dynamics	**Bath Iron Works (BIW)**	Surface Combatant	• Arleigh Burke Class Destroyer (DDG 51) • Zumwalt Class Destroyer (DDG 1000)
	Electric Boat (EB)	Submarine	• Ohio Replacement Submarine • Virginia Class Submarine (SSN 774)
	NASSCO	Command/Support	• Expeditionary Transfer Dock (ESD)/Expeditionary Mobile Base (EMB)
		Combat Logistics	• TAO Fleet Oiler
Huntington Ingalls	**Newport News**	Aircraft Carrier	• Gerald R. Ford Class (CVN 78)
		Submarine	• Ohio Replacement Submarine • Virginia Class submarine (SSN 774)
	Ingalls	Surface Combatant	• Arleigh Burke Class Destroyer (DDG 51)
		Amphibious Warfare	• San Antonio Class Amphibious Transport Dock (LPD 17) • America Class Amphibious Assault (LHA 6)
		Cutters	• National Security Cutters (WMSL)
Fincantieri	**Marinette Marine (MM)**	Surface Combatant	• Littoral Combat Ship (LCS)
Austal	**Austal**	Surface Combatant	• Littoral Combat Ship (LCS) • Expeditionary Fast Transport (EPF)

Long Term Challenges

The Ohio Replacement program remains the top priority for DoN and part of the national defense strategy to modernize the sea-based strategic deterrent submarine. The long-term challenge for DoN is balancing the procurement of the Ohio Replacement program without impacting remaining shipbuilding programs. Changes in ship procurement plans have a major impact on the shipyards and lower-tier suppliers' workload. The timing of ship procurements is critical to sustain the workload required to support the shipyards viability and sustain a skilled workforce.

The Navy will continue working with Congress to maximize the benefits of the National Sea-Based Deterrent Fund, Economic Order Quantity, Advance Construction, and Incremental Funding authorities in order to mitigate the risks to other battle force ships due to funding requirements for the Ohio Replacement program.

Mitigation Efforts

Stability and predictability are critical for the shipbuilding industrial base. In order to maintain stability in the sector, the Navy is involving the shipyards early in the design process, supporting shipbuilding capabilities preservation agreements, and promoting block buys and multiyear procurement strategies. Through acquisition strategies, the Navy is promoting dual sourcing options to drive innovation and reduce costs. For example, awarding a program design contract to multiple shipyards stimulates competition, accelerates innovation through collaboration, and ensures that designs are stable before entering into production.

The Navy is also monitoring the health of major suppliers and the quality trends across industry. Construction plans have been developed to minimize impacts to the industrial base where possible in order to avoid future increases in cost above inflation or potential permanent losses to this national industrial capability.

Defense Mergers and Acquisitions

The Department examines potential transactions on a case-by-case basis. It is the Department's policy to oppose business combinations that:

- Overly reduce or eliminate competition;
- Limit innovation;
- Raise credible threats to national security; and
- Are not otherwise in the Department's ultimate best interest.

The Department reviews several types of business combinations involving defense suppliers:

- Proposed mergers or acquisitions filed under the Hart-Scott-Rodino Antitrust Improvement Act of 1976 (generally, transactions valued at more than $78.2 million in 2016);
- Other transactions and business relationships that are not considered by the antitrust agencies or those of special interest to the Department that do not meet the Hart-Scott-Rodino Act filing threshold; and
- Proposed acquisitions of U.S. defense-related firms by non-U.S. firms for which filings have been made pursuant to the Exon-Florio Amendment to the Omnibus Trade and Competitiveness Act of 1988, as amended by the Foreign Investment and National Security Act of 2007, (P.L. 110-49).

The first two review types are conducted under M&A reviews pursuant to DoD Directive 5000.62, "Impact of Mergers, Acquisitions, Joint Ventures, Investments, and Strategic Alliances of Suppliers on National Security and Public Interests." The third type of review is conducted by the Department under CFIUS.

Major Defense Supplier M&A Reviews

The Federal Trade Commission (FTC) and the Department of Justice (DoJ) (the "Antitrust Agencies") have the statutory responsibility to determine the likely effects of a defense industry merger on the performance and dynamics of a particular market and whether a proposed merger should be challenged on the grounds that it may violate antitrust laws. As the primary customer affected by defense business combinations, DoD's views have been particularly significant because of its special insight into a proposed merger's impact on innovation, competition, national security, and the defense industrial base. Accordingly, the Department actively works with the Antitrust Agencies but also independently addresses issues where appropriate.

The Department's transaction reviews are structured to identify impacts on competition, national security, and defense industrial capabilities. The reviewers evaluate the potential for loss of competition for current and future DoD programs, contracts and subcontracts, and for future technologies of interest to the Department. In addition, the reviews address any other factors resulting from the proposed combination that may adversely affect the satisfactory completion of current or future DoD programs or operations. The policies and responsibilities for assessing major Defense supplier M&A reviews are identified in DoD Directive 5000.62. While these reviews can include transactions that are also evaluated in the CFIUS review process, the issues considered are distinct.

The Department's current policy is to conduct assessments of proposed business combinations on a case-by-case basis and to support the Antirust Authorities' review process. The Department's reviews have included the consideration of potential impacts on national security, but recent transactions have demonstrated that the current antitrust provisions may be too narrowly constrained. Transaction reviews in 2016 demonstrated that previous concerns regarding the lack of authorities to address national security issues arising from transactions was not an isolated occurrence. The current law only prohibits M&A that are found to lessen competition or which tend to create a monopoly. Potential national security implications associated with a proposed transaction are not considered. Reviewing transactions to assess the national security implications is critical to stewardship of an industrial base structure needed to meet national security objectives. Defense firms are not just other commercial businesses. They provide a critical service to the nation, providing the equipment and support that our armed forces use to ensure the security of our country.

DoD transaction reviews are structured to identify impacts on competition, national security, and defense industrial capabilities

The Department will continue to work closely with the Antitrust Authorities to ensure that transactions do not reduce competition or cause market distortions that are not in the Department's ultimate best interest. DoD relies on robust, credible competition to provide high-quality, affordable, and innovative products. The trend toward fewer and larger prime contractors has the potential to affect innovation, narrow industrial capabilities and technology, limit the supply base, pose entry barriers to small, medium and large businesses, and ultimately reduce competition, or may otherwise not be in the Department or the public's interests. The Department is mindful of the past loss of peer-to-peer competition at the prime level, resulting from significant industry consolidations over the past twenty-plus years. The Department has been concerned about M&A among the top tier of weapons suppliers for some time and does not view consolidation among our top weapon system primes as a favorable development.

The competitive dynamics and the positioning of defense firms are significantly different today than in the 1990s. With the excess capacity resulting from the budget decline at that time, the Department anticipated that consolidation rationalization benefits would offset harm to competition. In retrospect, the proposed benefits may not have been realized to the extent anticipated. Today, there is a lower potential for M&A-derived reductions of excess capacity and overhead to offset the loss of competition, and the Department is increasingly skeptical about proposed benefits. In response to the recent budget restrictions, the major defense contractors largely addressed expenditure declines through internal rationalization through workforce and facility footprint reductions. Therefore, the Department does not currently believe consolidation is systemically necessary among major suppliers and prime contractors to maintain healthy industrial base dynamics.

Major Defense Supplier M&A Activity in 2016

In 2016, the Department completed 12 reviews of significant transactions out of the approximately 380 defense-related M&A over the course of the year. Figure 27 highlights the aggregate number and value of these transactions, as reported by InfoBase. While the total value of the transactions in 2016 has spiked since the trough in 2013 and 2014, the number of transactions has remained steady. The spike in the aggregate deal valuation is led by Berkshire Hathaway's $37.2 billion acquisition of Precision Castparts.

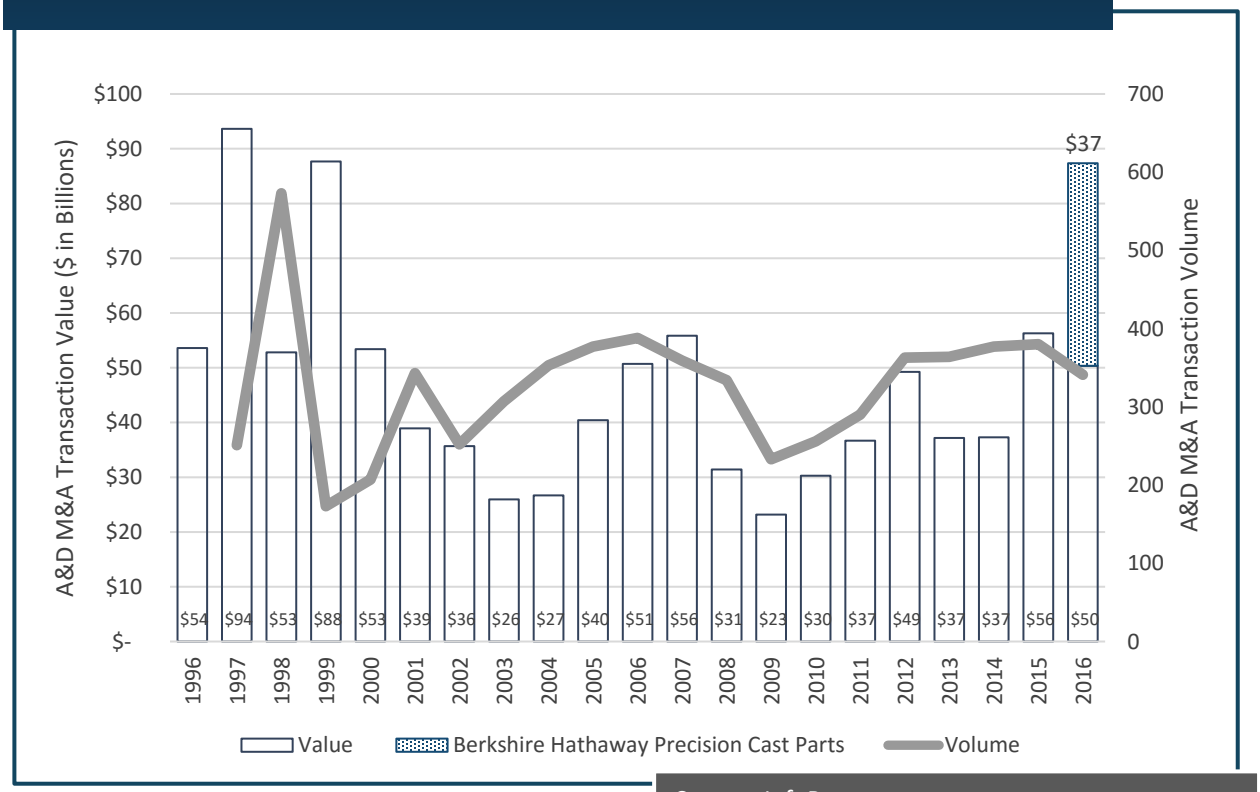
The Department reviewed a wide range of transactions in 2016, including Leidos' $4.6 billion acquisition of a restructured Lockheed Martin's Information Systems & Global Solutions in a tax-free Reverse Morris Trust merger (where technically Lockheed Martin was the "buyer" as its shareholders held 50.5% of the new company when the deal was executed). The review included an assessment of the competitive landscape for the nine primary service categories and the six critical knowledge-based service categories involving the major service contractors.

TransDigm Group's three acquisitions in 2016 continued the company's model of purchasing Aerospace and Defense firms which hold monopoly or single-source positions on proprietary and highly-engineered components with high barriers to entry, with subsequent price hikes.

During 2016, two previously proposed transactions including Smiths Group's proposal to acquire Safran's Morpho Detection, previously GE Homeland Protection, were repeated.

While not concluded by the end of 2016, last year also included a transaction proposed by Infineon to acquire Cree's Wolfspeed for $850 million. The review included addressing potential risks involving the future of a DoD "crown jewel" industrial base partner. Cree's Wolfspeed is a critical merchant supplier of high-purity Silicon Carbide (SiC) wafer substrates and finished products using specialized Epitaxy (GaN-on-SiC or SiC-on-SiC) for defense RF and Power applications. Cree has maintained a close working relationship with the Department as a legacy of almost 30 years of investments from Title III of the DPA, ManTech, DARPA, Military Services, and the Department of Energy (DoE).

Figure 27: Defense Related M&A Transactions



Source: InfoBase

Committee on Foreign Investment in the United States

Section 721 of the DPA of 1950 (50 U.S.C. Section 4565) authorizes the President, acting through CFIUS, to review any merger, acquisition, or takeover proposed by any foreign person that could result in foreign control of any person engaged in interstate commerce in the United States (a "covered transaction"). The Committee is chaired by the Secretary of the Treasury and includes the Secretaries of State, Defense, Commerce, Energy, and Homeland Security, the Attorney General of the United States, the Office of Science & Technology Policy, and the United States Trade Representative.

A CFIUS review is intended to determine the effects of a covered transaction on the national security of the United States. The factors affecting national security, which the Committee may consider as part of this review, are broad, including:

- The capability and capacity of domestic industries to meet national defense requirements;
- The control of domestic industries and commercial activity by foreign citizens as it affects the capability and capacity of the U.S. to meet the requirements of national security;
- The potential effects on sales of military goods, equipment, or technology to countries involved in terrorism, proliferation, or that pose a potential regional military threat to the interests of the U.S.;
- Potential effects on U.S. international technological leadership in areas affecting U.S. national security;
- Potential effects on U.S. critical infrastructure, including major energy assets;
- Potential effects on U.S. critical technologies;
- Whether the transaction could result in the control of any person engaged in interstate commerce in the U.S. by a foreign government, either directly or indirectly; and
- Such other factors as the President or CFIUS may determine to be appropriate.

MIBP, on behalf of USD (AT&L), has the lead within the Department in representing the Department at CFIUS. MIBP coordinates its work on CFIUS matters with a wide range of internal Department stakeholders and experts. Pursuant to 10 U.S.C. Section 2537(c), the Defense Intelligence Agency provides the Department with an assessment of the risks of unauthorized technology transfer and diversion. Pursuant to the Foreign Investment and National Security Act of 2007 (FINSA) (P.L. 110-49), the Office of the Director of National Intelligence prepares a national security threat assessment for CFIUS that evaluates potential threats posed by the acquiring firm and country.

Programs and Actions to Sustain Capabilities

The Defense Production Act

DPA, as amended (50 U.S.C. App., §2061 et seq.), articulates that "the security of the United States is dependent on the ability of the domestic industrial base to supply materials and services for the national defense and to prepare for and respond to military conflicts, natural or man caused disasters, or acts of terrorism within the United States." For the purposes of the DPA, "national defense" means programs for military and energy production or construction, military, or critical infrastructure assistance to any foreign nation, homeland security, stockpiling, space, and any other directly related activity. National defense also includes emergency preparedness activities conducted pursuant to Title VI of the Robert T. Stafford Disaster Relief and Emergency Assistance Act (Stafford Act) (42 U.S.C. § 5195 et seq.) and critical infrastructure protection and restoration.

Major DPA provisions include:

- The authority to require acceptance and priority performance of contracts and orders to promote the national defense (DPA section 101);
- The authority to allocate materials, services, and facilities in such manner, upon such conditions, and to such extent as deemed necessary or appropriate to promote the national defense (DPA section 101);
- Financial incentives and assistance for industry to reduce current or projected shortfalls of resources essential for the national defense; or to create, maintain, protect, expand, or restore domestic industrial base capabilities essential for the national defense (DPA Title III);
- Antitrust protection for voluntary agreements and action plans among business competitors to enable cooperation to plan and coordinate measures to increase the supply of materials and services needed for the national defense (DPA section 708);

"Marry up our people with advanced technology, and you will have a force that will dominate any adversary, any time, in any alternative future."

Deputy Secretary of Defense
Bob Work

"Remarks to the Air Force Association"
National Harbor, MD
September 21, 2016

- The authority to establish a cadre of persons with recognized expertise for employment in executive positions in the Federal Government in the event of an emergency (DPA section 710(e)); and
- The authority to review certain mergers, acquisitions, and takeovers by or with any foreign person that could result in foreign control of any person engaged in interstate commerce in the United States (DPA section 721).
- DPA Title III is the primary statutory authority to ensure the timely availability of industrial resources and critical technologies essential for our national defense. For the purposes of the DPA, "national defense" means programs for military and energy production or construction, military, or critical infrastructure assistance to any foreign nation, homeland security, stockpiling, space, and any other directly related activity.

DPA Title III permits the use of special economic incentives to "develop, maintain, modernize, and expand the productive capacities of domestic sources for critical components, critical technology items, and industrial resources." The Title III Program is unique among DoD programs because its central focus is to address challenges facing domestic production capacity, and this program has a well-established record as an exceptionally effective tool for transitioning new technologies from research and development to production. By providing industry with a variety of incentives to reduce the risks associated with establishing the needed capacity, the program is able to facilitate the expansion of domestic capacity and ensure the production of critical defense technology.

DPA Title III industry partners have revolutionized the technology behind LED lighting, transformed the processes of advanced composite fiber placement, modernized manufacturing for critical rocket motors, and achieved many more technological successes. As the program looks to the future, expanded capacity in cybersecurity, unmanned technologies, future fuel sources, and developing innovations, will be central to the success of the warfighter's mission. DPA Title III is well-positioned to accelerate DoD exposure to these emerging technology sectors in order to expand the technological superiority of the United States for decades to come.

In 2016, the DPA Title III Program was actively managing 21 projects and was overseeing 6 projects in the No-Cost-Monitoring-Phase. Two projects were completed and 17 projects are being explored or in active acquisition. For more complete details about these specific projects, see Appendix C of this report.

DoD Manufacturing Technology Program

Providing warfighters with cutting-edge capabilities in a timely manner means turning scientific discoveries or inventions into affordable, operational and integral products. The DoD ManTech program serves as an enabler of technology transition by bringing affordable technologies to acquisition program managers through new manufacturing and production processes and equipment.

Defense acquisition programs rely on innovative manufacturing capabilities and an industrial base that can use these capabilities to deliver products that meet the needs of the warfighter. In the 20th century, when the threat was highly predictable and the U.S. defense industrial base was largely self-contained, ManTech helped keep the nation positioned to provide the best military systems in the world. In the 21st century, the DoD faces a range of strategic, conventional and asymmetric challenges while the U.S. technological advantage is under strain and the defense industrial base is increasingly reliant on commercial capabilities. To address these challenges and equip America's warfighters, program managers are tapping a globally networked and diverse industrial base. Compounding this complexity is the increasing imperative to consider affordability in the DoD's science and technology, acquisition and sustainment plans. These are the new demands placed on defense manufacturing, and they are shaping the role of ManTech.

The program's mission is both multi-faceted and vital; namely, DoD ManTech anticipates and closes gaps in manufacturing capabilities for affordable, timely, and low-risk development, production, and sustainment of defense systems as illustrated in Figure 28. The program looks beyond the normal risk of industry and directs investments at improving the quality, productivity, technology and practices of businesses and workers that provide goods and services to the DoD. ManTech focuses on enabling the affordable and timely development, production and sustainment of defense systems, thereby enhancing our technological edge in a dynamic, diverse and evolving threat environment.

Figure 28: ManTech Program Mission

Section 2521 of Title 10 U.S.C. 2521 requires the USD(AT&L) to administer the DoD ManTech Program on behalf of the Secretary of Defense, and this is further delegated to the DASD(MIBP), which exercises OSD-level oversight of the ManTech Program pursuant to 10 U.S.C. 139c. Component ManTech programs are individually executed by the Departments of the Army, Navy, Air Force, DLA, MDA and OSD. Although all Component ManTech programs work in concert toward common goals, each has important focus areas to meet individual Component mission needs.

- *The Army ManTech Program* is structured around enabling manufacturing improvements of components and subsystems for ground, soldier/squad, air, lethality and command, control, communications and intelligence systems.
- *The Navy ManTech Program* is focused on reducing the acquisition cost of current and future platforms, resulting in an investment strategy currently focused on five ship platforms and the F-35 and CH-53K aircraft.
- *The Air Force ManTech Program* is the DoD's lead for manufacturing technology in aerospace propulsion, structures, intelligence, surveillance and reconnaissance and is the only Air Force corporate program working strategic issues and opportunities in manufacturing and industrial readiness. Manufacturing technology plays a pervasive role in enabling many Air Force Science and Technology Strategy priorities, chiefly through attaining next-generation agile manufacturing.
- *The DLA ManTech Program* focuses on sustaining the war-fighters and improving materiel readiness. Ongoing efforts support improvements in availability of microcircuits, combat rations, clothing and protective equipment, batteries, forgings and castings.
- *The OSD-managed Defense-wide Manufacturing Science and Technology (DMS&T) Program* takes a broad, overarching view toward closing critical gaps in cross-cutting, military manufacturing enabling technologies that will have significantly impact multiple Military Departments or platforms.

In particular, MIBP has the organizational visibility and access to policy and investment levers to enable more coherent and integrated approaches to maintaining the full suite of necessary defense manufacturing enterprise capabilities. Other programs, such as the industrial base sector assessments performed within MIBP, also inform ManTech investment decisions.

The Joint Defense Role – The component ManTech programs collaborate and coordinate their efforts through the JDMTP. The principals of the JDMTP are senior technology managers representing the Army, Navy, Air Force, DLA, MDA and OSD. Ex-officio members of the JDMTP include DARPA, National Institute of Standards and Technology, NASA, and DoE.

The JDMTP categorizes all ManTech investment areas by the technology portfolios of subpanels—the current subpanels are Electronics, Metals, Composites and Advanced Manufacturing Enterprise—enabling component ManTech programs to maximize opportunities for shared investment in initiatives and strategies with joint application and to prevent duplication of effort. In addition, Joint Technical Pursuit Areas (JTPAs) are developed as part of the annual planning cycle. JTPAs represent manufacturing challenges, which cross-cut multiple Services and multiple systems; topics which are beyond the risk for a single Service which supports the need to balance mission-specific priorities of Service ManTech Programs with broader Joint-Service priorities, which can deliver significant advantages to the defense industrial base.

The JDMTP and MIBP jointly developed a 2012 DoD ManTech Program Strategy that recognizes the ManTech Program's central role within the defense manufacturing enterprise and its extended impacts and leverage across the defense industrial base and broader national security environment.

The theme of the strategy is Delivering Advanced, Affordable Manufacturing for the Warfighter, and the following four strategic thrusts (with supporting enabling goals) have been established to unify and guide the joint ManTech enterprise, consistent with the USD(AT&L)'s BBP initiatives and the defense manufacturing vision and ManTech Program mission:

- *Thrust 1:* A Responsive and Balanced Manufacturing Technology Investment Portfolio to Meet DoD Requirements.
- *Thrust 2:* Active Support for a Highly Connected and Collaborative Defense Manufacturing Enterprise.
- *Thrust 3:* Active Support for a Strong Institutional Focus on Manufacturability and Manufacturing Process Maturity.
- *Thrust 4:* Active Support for a Healthy, Sufficient, and Effective Defense Manufacturing Infrastructure and Workforce.

The framework illustrated in Figure 29 establishes the program's core focus on ensuring responsiveness and balance across the full portfolio of manufacturing technology investments (Thrust 1), and it couples that focus with the objective to actively and collectively support broader defense manufacturing needs (Thrusts 2, 3, and 4). This approach underscores the importance of program support for these broader needs while recognizing it is beyond the program's charter and resources to fully satisfy them. Even so, each of these four thrusts directly supports the Secretary of Defense's current strategic guidance in key ways. In particular, processing and fabrication breakthroughs enable affordable production for effective modernization; material and manufacturing investments made concurrently with science and technology (S&T) R&D projects deliver technological superiority to the Warfighter quickly; and enterprise level initiatives create more connected and collaborative environments, a stronger focus on manufacturability, and improved manufacturing infrastructure. All of these support the maintenance of a healthier and more resilient industrial base.

Figure 29: ManTech Framework

Manufacturing USA Institutes

It was out of the DMS&T program that the seeds were planted for the DoD to embrace industry and academia in broader public-private collaboration to enhance national manufacturing capabilities, including those with likely defense applications. In 2012, the Department was asked to be one of the leads in an effort to create a whole of government network focused on advanced manufacturing. This program seeks to create a robust national innovation ecosystem composed of a growing network of regionally based but nationally impactful manufacturing institutes across the United States. Each has a technical focus area of high importance to both the federal government and to industry.

In support, DoD provided key funding, technical leadership, and program management support to successfully launch the $110 million "pilot" institute, the National Additive Manufacturing Innovation Institute. Now called "America Makes," the Institute officially opened on September 27, 2012, and it serves as a training and collaboration center to bridge the gap between basic research and technology adoption for additive manufacturing design and technologies. More commonly known as "3D printing," additive manufacturing is an enabling manufacturing technology for our military platforms. Participants include DoD, DoE, NASA, National Science Foundation (NSF), and the DoC's National Institute of Standards and Technology (NIST). The interagency investment of $55 million has been matched by a $55 million cost share from non-Federal sources, and this institute has the goal of becoming self-sufficient within five years.

Building upon that success, DoD then led an effort to launch two new public-private partnerships for Advanced Manufacturing on behalf of the Department: the Digital Manufacturing and Design Innovation Institute (DMDII) and Lightweight Innovations for Tomorrow (LIFT).

The $176 million DMDII, headquartered in Chicago, Illinois, focuses on enterprise-wide utilization of the digital thread, enabling highly integrated manufacturing and design of complex products at reduced cost and time. The digital thread captures information generated from concept development and design to analysis, planning, manufacturing, assembly, maintainability, and through to disposal. By demonstrating the potential for integrating information technology, smart factory processes, intelligent machines, and sophisticated analytics, DMDII will be a key competitive differentiator for the U.S. industrial base.

The $148 million LIFT institute, headquartered in Detroit, Michigan, focuses on the design of lightweight systems, including the design of lightweight materials, the design of manufacturing operations to produce lightweight components, and the integration of these designs into revolutionary new lightweight systems. During the past 15 years, significant U.S. investments in lightweight metals, intended for demanding critical applications, have not transitioned into the marketplace due to cost of necessary scale-up and certification requirements. Defense, transportation, energy, and automotive industrial segments all benefit significantly from lightweight structures and components. By integrating the emerging capabilities in materials and process design, with the design of new lightweight components and products, the speed at which products enter the marketplace can be accelerated, at competitive price points, and drive global competitiveness.

In 2015, the ManTech Program continued its successes by establishing two additional institutes, with technical focus areas of integrated photonics (IP) manufacturing and flexible hybrid electronics manufacturing.

AIM Photonics, with $600 million of total funding, will seek to automate the assembly of integrated photonics systems to minimize the touch-labor component, whose high cost has prompted industry to seek offshore production solutions in recent decades. Headquartered in Albany, New York, with founding academic partners in California, Massachusetts, and Arizona, AIM Photonics will bring government, industry, and academia together to organize the current fragmented domestic capabilities in integrated photonics and better position the U.S. to compete globally. IP applications include ultra-high speed data and communications, high-performance IT systems, medical diagnostics, and multiple sensor integrations.

The Manufacturing USA network of institutes directly support the national agenda to aggressively develop and sustain world-leading, advanced manufacturing capabilities

The second institute, NextFlex, is headquartered in San Jose, California, with total funding of $176 million. NextFlex will focus on innovative processes at the intersection of the electronics industry and the high-precision printing industry, with the power to create electronics or sensors that are lighter in weight, or conform to the curves of a human body, while preserving the full operational integrity of traditional electronic architectures. Integrating ultra-thin silicon components through high-precision handling, printing with conductive and active inks, and printing to integrate on stretchable substrates, flexible hybrid technologies can improve the connectivity of devices through the Internet of Things. Applications of flexible hybrid electronics include medical monitoring, asset tracking, soft robotics, and highly integrated wearables.

During 2016, ManTech established its sixth manufacturing institute. AFFOA is headquartered in Cambridge, MA and focuses on manufacturing of technical textiles, consisting of fibers and fabrics with extraordinary properties of strength, flame resistance, and electrical conductivity. These technical textiles are built upon a foundation of synthetic, natural fiber blends, and/or multi-material fibers that have a wide-range of applications in both the defense and commercial sector that go beyond traditional wearable fabrics. Two additional institutes are planned for award in FY2017 based upon opportunities and key demand signals from DoD, industry, and academia.

In addition to the DoD-led institutes, DoE has established two manufacturing institutes focused on wide bandgap semiconductor power electronics and advanced composites. Each of these institutes are members of Manufacturing USA network of institutes. The Manufacturing USA network of institutes formed to directly support the national agenda to aggressively develop and sustain world-leading, advanced manufacturing capabilities. Congress authorized the establishment of a national network as part of the Revitalize American Manufacturing and Innovation Act of 2014.

Industrial Base Analysis and Sustainment Program

IBAS Framework

The IBAS program's main objective is to address critical capability shortfalls in the defense industrial base. Capabilities that are at-risk of being lost and cross Service/DoD-Agency boundaries are specifically targeted. The goal is not to sustain all capabilities indefinitely, but to avoid reconstitution costs when capabilities are likely to be needed in the foreseeable future. IBAS makes investments only when sustainment is more cost-effective than reconstitution and results in overall cost avoidances to the Department.

The three areas of IBAS focus are:

- *Unique Capabilities* – Lifelines and safe harbors for critical, unique capabilities with fragile business cases
- *Design Teams* – Preserving critical skills for technological superiority
- *Industrial Base Supply, Expansion & Competition* – Supporting expansion of reliable sources

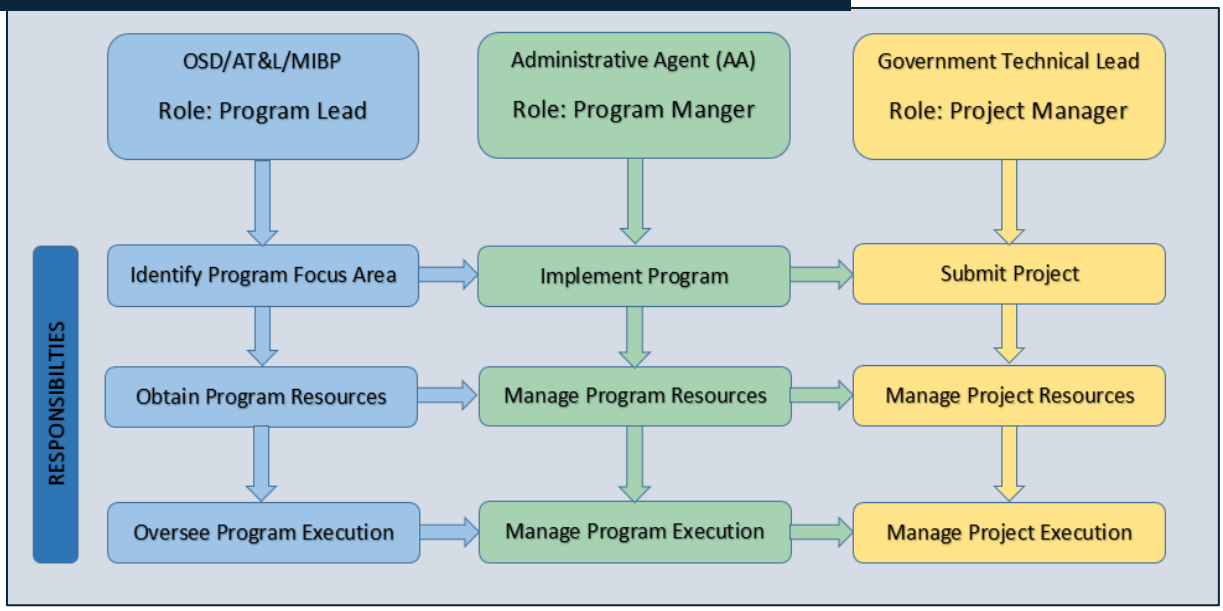
Proposals for IBAS funding are evaluated in a four step process. First, proposals are reviewed for alignment with MIBP and IBAS program objectives. Second, proposals are scored against established FaC criteria. Third, proposals are ranked by a multi-Service/multi-Agency Joint Industrial Base Working Group (JIBWG) review panel. Fourth, DASD(MIBP) evaluates the review panel results and makes the final selections for IBAS funding.

The IBAS Program is executed according to the framework illustrated in Figure 30. The ultimate responsibility for program execution lies with MIBP. The office is responsible for ensuring the areas being addressed are based upon the latest vulnerability information associated with the defense industrial base. Focus areas can change year to year for a variety of reasons including budget shifts, changes in risk, and technology advancements that can render current capabilities obsolete.

While MIBP is responsible for submitting and tracking the annual budget requests and execution, they depend upon an Administrative Agent for actual day-to-day management of the program. This agent calls for project proposal submissions, tracks project progress, and interacts with the individual Government technical leads who directly liaison with the principle performers of the work. They follow the program strategy as directed by the MIBP program office while pre-screening all proposals submitted for consideration and provide an evaluation and ranking/recommendation.

IBAS project requirements come from a variety of different sources. Major sources include a general call for proposals to the DoD SAEs and Agencies; engagement with sector specific working groups such as the SIBWG or the CEMWG; and the industrial base FaC assessment results.

Figure 30: IBAS Program Framework



IBAS is successfully supporting the National Defense Strategy by maintaining and improving the health of critical and fragile industrial base capabilities that are at risk of being lost advanced manufacturing capabilities

Program Details

Since program inception, IBAS has sponsored 17 major efforts during FY2014 through FY2016. These programs have preserved fundamental capabilities across the IB in all three of the IBAS focus areas. See Appendix C for descriptions of projects.

IBAS is successfully supporting the National Defense Strategy by maintaining and improving the health of critical and fragile industrial base capabilities that are at risk of being lost. Projects address cross-service capabilities at risk of "falling through the cracks." The IBAS sustainment of these capabilities has shown great success in keeping critical industrial capabilities alive, enhancing the readiness and effectiveness of our National Defense, and lowering total cost to DoD.

Conclusion

In FY2016, the Department continued its progress in aligning its ability to maintain and expand the defense industrial base. MIBP helped lead DoD's efforts to identify, assess, and mitigate the Department's industrial base concerns through the utilization of various programs and activities. Highlights of FY2016 activities included:

- Expansion of the use of DIUx with plans to establish an east-coast capability in the Boston, MA area to improve DoD's collaboration with both traditional defense contractors and the non-traditional commercial high-tech industry;
- Establishment of MD5 and the execution of activities in support of DoD human capital innovation and civil-military industry innovation objectives;
- Establishment of one new Manufacturing USA Institute, AFFOA, and commitment to establish two additional institutes by the end of 2017 based upon opportunities and demand signals from DoD, industry, and academia;
- Conduct industrial base assessments on munitions, SRMs, microelectronics, and space-based areas;
- Convened two IBC executive level forums for senior DoD leaders to review and discuss key defense industrial base trends and issues that focused on foreign direct investments, cyber security, and other far reaching trends impacting the defense industrial base;
- Conduct seventeen IBAS projects to preserve industrial capabilities, primarily in the missile and space industrial sectors since the program's inception.

The changing nature of warfare and sources of innovation as well as the increasingly complex global market trends significantly impact the health and stability of the defense industrial base. Bold leadership and sophisticated strategies are therefore essential to support this critical part of DoD's force structure. The Department's leadership responded proactively to these challenges in 2016 and the initiatives undertaken will help to develop and strengthen the nation's vital industrial base capabilities for the coming years.

MIBP completed phase one development of a BI&A analytic platform to enhance its efforts to better anticipate and mitigate weaknesses in the defense industrial base and plans to develop phase two in the coming year. This technology platform coupled with continuous improvements and closer Government-private sector collaboration will help the Department navigate to a future industrial base that successfully addresses tomorrow's national security challenges.

Appendix

- Appendix A: Annual Report Requirements
- Appendix B: Summary of Key Industrial Capabilities Assessments Completed During FY2016
- Appendix C: Related Activities
- Appendix D: List of Acronyms
- Appendix E: Photo Credits

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 DoD 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.

Section 852 of the National Defense Authorization Act for FY 2012, required that the annual report to Congress on the defense industrial base submitted for FY 2012, pursuant to section 2504 of title 10, U.S.C., includes a description of, and a status report on, the sector-by-sector, tier-by-tier assessment of the industrial base undertaken by DoD. As required, the report included a description of the steps taken and planned to be taken:

(1) To identify current and emerging sectors of the defense industrial base that are critical to the national security of the United States;

(2) In each sector, to identify items that are critical to military readiness, including key components, subcomponents, and materials;

(3) To examine the structure of the industrial base, including the competitive landscape, relationships, risks, and opportunities within that structure;

(4) To map the supply chain for critical items identified under paragraph (2) in a manner that provides the Department of Defense visibility from raw material to final products; and

(5) To perform a risk assessment of the supply chain for such critical items, and conduct an evaluation of the extent to which:

(a) the supply chain for such items is subject to disruption by factors outside the control of DoD; and

(b) such disruption would adversely affect the ability of DoD to fill its national security mission.

(c) Follow-up Review.—The Secretary of Defense shall ensure that the annual report to Congress on the defense industrial base, submitted for each of FYs 2013, 2014, and 2015, includes an update on the steps taken by DoD to act on the findings of the sector-by-sector, tier-by-tier assessments of the industrial base and implement the strategy required by section 2501 of title 10, U.S.C. Such updates shall, at a minimum:

- Be conducted based on current mapping of the supply chain and industrial base structure, including an analysis of the competitive landscape, relationships, risks, and opportunities within that structure; and

- Take into account any changes or updates to the national defense strategy, National Military Strategy, national counterterrorism policy, homeland security policy, and applicable operational or contingency plans.

The Senate Report 112-26 accompanying S. 1253, the National Defense Authorization Act for FY 2012, noted at pages 65-66 that the Senate Armed Services Committee is interested in how the determination of DPA Title III projects will be linked to the outcome of the S2T2 assessments, which would identify sectors of the defense industrial base that may require additional resources. The committee requested the DASD(MIBP) to submit an annual report by April 1st to the congressional defense committees containing a prioritized list of potential investments required to address industrial base shortfalls to be expected to be funded by the Department in future years through the DPA Title III program. This report contains the required information.

This report simultaneously satisfies the requirements pursuant to title 10, U.S.C., section 2504, which requires the DoD 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: Key Industrial Capabilities Assessments Completed During FY2016

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

Appendix C: Related Activities

C.1 Defense Production Act Summaries

Appendix C.1 contains information for official use only, business confidential, and proprietary. This appendix will be provided separate from this report.

C.2 IBAS Activity Summaries

Appendix C.2 contains information for official use only, business confidential, and proprietary. This appendix will be provided separate from this report.

Appendix D: List of Acronyms

A&D	Aerospace and Defense
AALN	Adaptive Agile Leader Network
AARGM-ER	Advanced Anti-Radiation Guided Missile Extended Range
AAV	Amphibious Assault Vehicle
ACV	Amphibious Combat Vehicle
AEHF	Advanced Extremely High Frequency
AESA	Active Electronically Scanned Arrays
AFFOA	Advanced Functional Fabrics of America
AFRL	Air Force Research Laboratory
AIA	Aerospace Industries Association
AMDR	Air and Missile Defense Radar
AMF	Airborne & Maritime/Fixed Station
AMPAC	American Pacific
AMPV	Armored Multi-Purpose Vehicle
AMRAAM	Advanced Medium-Range Air-to-Air Missile
AOC	Air and Space Operations Center
AP	Ammonium Perchlorate
APC	Armored Personal Vehicle
AR	Aerojet Rocketdyne
ASIC	Application Specific Integrated Circuit
AT&L	Acquisition, Technology, and Logistics
ATACMS	Army Tactical Missile System
BAE	British Aerospace Systems
C4	Command, Control, Communication, and Computers
CAC2S	Common Aviation Command and Control System
CANES	Consolidated Afloat Networks and Enterprise Services
CEC	Cooperative Engagement Capability
CEMWG	Critical Energetics Materials Working Group
CFIUS	Committee on Foreign Investment in the United States
CIRCM	Common Infrared Countermeasures
CS	Combat Support
CSS	Combat Service Support
CVN 78	Gerald R. Ford Class
DAGR	Defense Advanced GPS Receiver
DARPA	Defense Advanced Research Projects Agency
DASD	Deputy Assistant Secretary of Defense
DCGS-A	Distributed Common Ground System-Army

DD&C	Detail Design and Construction
DDG 1000	Zumwalt Class Destroyer
DDG 51	Arleigh Burke Class Destroyer
DDI	Dimeryl-di-isocyante
DFARS	Defense Federal Acquisition Regulation Supplement
DIUx	Defense Innovation Unit Experimental
DLA	Defense Logistics Agency
DMAG	Deputy's Management Action Group
DMDII	Digital Manufacturing and Design Innovation Institute
DMEA	Defense Microelectronics Activity
DMS&T	Defense-wide Manufacturing Science and Technology
DMS-M	Defensive Management System Modernization
DNA	Deoxyribonucleic Acid
DoC	Department of Commerce
DoD	Department of Defense
DoDIN	Defense Information Network
DoE	Department of Energy
DoJ	Department of Justice
DoN	Department of Navy
DPA	Defense Production Act
DPAS	Defense Priorities and Allocation Systems
DPG	Defense Planning Guidance
DSC	Defense Space Council
DTRA	Defense Threat Reduction Agency
EA	Executive Agent
EBITDA	Earnings Before Interest, Taxes, Appreciation, and Amortization
EELV	Evolved Expendable Launch Vehicle
EMB	Expeditionary Mobile Base
EMD	Engineering and Manufacturing Development
EPF	Expeditionary Fast Transport
ESAD	Electronic Safe and Arm Device
ESD	Expeditionary Transfer Dock
ESSM	Evolved Sea Sparrow Missile
EW	Electronic Warfare
FAB-T	Family of Advanced Beyond Line-of-Sight Terminals
FaC	Fragility and Criticality
FAR	Federal Acquisition Regulation
FDI	Foreign Direct Investment
FHTV	Family of Heavy Tactical Vehicles
FMS	Foreign Military Sales

FMTV	Family of Medium Tactical Vehicles
FPGA	Field Programmable Gate Array
FRP	Full Rate Production
FTC	Federal Trade Commission
FVL	Future Vertical Lift
FY	Fiscal Year
FYDP	Future Years Defense Program
G/ATOR	Ground/Air Task Oriented Radar
GaN	Gallium Nitride
GBSD	Ground Based Strategic Deterrent
GCV	Ground Combat Vehicles
GIDEP	Government- Industry Data Exchange Program
GNC	Guidance, Navigation, and Control
GPS	Global Positioning System
HD4	Hacking for Defense
HEMTT	Heavy Expanded Mobility Tactical Trucks
HIMARS	High Military Rocket Systems
HMMWV	High Mobility Multi-Purpose Wheeled Vehicle
HMS	Handheld, Manpack, and Small Form Fit
HTPB	Hydroxyl-terminated Polybutadiene
IAMD	Integrated Air and Missile Defense
IBAS	Industrial Base Analysis and Sustainment
IBC	Industrial Base Council
IC	Integrated Circuit
ICBM	Inter-Continental Ballistic Missile
IDECM	Integrated Defensive Electronic Countermeasures
IFV	Infantry Fighting Vehicles
IMU	Inertial Measurement Units
IP	Integrated Photonics
IPT	Integrated Project Team
ITV	Internally Transportable Vehicles
JAGM	Joint Air to Ground Missile
JANNAF	Joint Army Navy NASA Air Force
JASSM-ER	Joint Air-to-Surface Standoff Missile – Extended Range
JDAM	Joint Direct Attack Munition
JDMTP	Joint Defense Manufacturing Technology Panel
JIBWG	Joint Industrial Base Working Group
JLTV	Joint Light Tactical Vehicle
JMR	Joint Multi-Role
JPALS	Joint Precision Approach and Landing System

JTPA	Joint Technical Pursuit Area
JTRS	Joint Tactical Radio System
LAV	Light Armored Vehicle
LCS	Littoral Combat Ship
LED	Light Emitting Diode
LHA 6	America Class Amphibious Assault
LIFT	Lightweight Innovations for Tomorrow
LPD 17	San Antonio Class Amphibious Transport Dock
LRASM	Long-Range Anti-Ship Missile
LRDR	Long Range Discrimination Radar
LRPF	Long Range Precision Fires
LVSR	Logistics Vehicle System Replacement
LX	Class Replacement
M&A	Mergers and Acquisitions
MAIS	Major Automated Information Systems
ManTech	Manufacturing Technology
MD5	Military District 5
MDA	Missile Defense Agency
MDAP	Major Defense Acquisition Program
MIBP	Manufacturing and Industrial Base Policy
MIDS	Multi-Functional Information Distribution System
MLRS	Multiple Launch Rocket Systems
MMIC	Monolithic Microwave Integrated Circuit
MPS	Mission Planning System
MRAP	Mine Resistant Ambush Protected
MRBM	Medium Range Ballistic Missile
MSE	Missile System Enhancement
MST	Maritime Strike Tomahawk
MTVR	Medium Tactical Vehicle Replacement
NASA	National Aeronautics and Space Administration
NATIBO	North American Technology and Industrial Base Organization
NDAA	National Defense Authorization Act
NDIA	National Defense Industrial Association
NDS	National Defense Stockpile
NGJ	Next Generation Jammer
NGLAW	Next Generation Land Attack Weapon
NGSC	Next Generation Strike Capability
NIST	National Institute of Standards and Technology
NNMI	National Network for Manufacturing Innovation
NRO	National Reconnaissance Office

NSA	National Security Agency
NSF	National Science Foundation
NSS	National Security Space
NSTC	National Science and Technology Council
O&M	Operations and Maintenance
OASD	Office of the Assistant Secretary of Defense
OASuW	Offensive Anti-Surface Warfare
OATK	Orbital ATK
OCX	Operation Control System
ODASD	Office of the Deputy Assistant Secretary of Defense
OSD	Office of the Secretary of Defense
OUSD	Office of the Under Secretary of Defense
PAC 3	Patriot Advanced Capability 3
PCAST	President's Council of Advisors on Science and Technology
PCB	Printed Circuit Board
PDSAS	Principal DoD Space Advisor Staff
PIM	Paladin Integrated Management
PLS	Palletized Load System
R&D	Research and Development
R&E	Research and Engineering
RAM	Rolling Airframe Missile
RDC	Rapid Deployment Capability
RDT&E	Research Development Test and Evaluation
RDX	Cyclotrimethylene Trinitramine
RHBD	Radiation Hardened by Design
SAE	Service Acquisition Executive
SBIR	Small Business Innovation Research
SBIRS	Space Based Infrared System
SDB	Small Diameter Bomb
SIBCP	Space Industrial Base Capability Program
SIBWG	Space Industrial Base Working Group
SiC	Silicon Carbide
SM-3	Standard Missile 3
SMC	Space and Missile Systems Center
SOTA	State of the Art
SRH	Strategic Radiation Hardened
SRM	Solid Rocket Motor
SSN 774	Virginia Class Submarine
STARNet	Semiconductor Technology Advanced Research Network
T/R	Transmit/Receive

TACTOM	Tactical Tomahawk
T-ATS	Fleet Ocean Tug
TFFS	Trust in FPGAs Feasibility Study
TMC	Tactical Mission Command
UAS	Unmanned Aircraft Systems
UA	Unmanned Aircraft
UCLASS	Unmanned Carrier-Launched Airborne Surveillance and Strike
ULA	United Launch Alliance
U.S.C.	United States Code
USD(AT&L)	Under Secretary of Defense, Acquisition Technology, and Logistics
USG	U.S. Government
WGS	Wideband Global SATCOM System
Win-T	Warfighter Information Network–Tactical
WMSL	National Security Cutters
WS	Weapon System

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