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ABSTRACT: The United States Aerospace and Defense (A&D) industry is a vital National Security (NS) interest and asset. This research explores ways the U.S. Government can strengthen the A&D industry by implementing constructive export controls, encouraging domestic defense competition, and bolstering the global supply chain. Economic projections of an ever-increasing federal debt burden will result in future challenges to the A&D industry through fewer government contracts and increased costs. Research on special topics offering assessments of the A&D industry outlook and current and future challenges offer policy recommendations to strengthen and sustain the A&D industry through increasingly tight fiscal constraints.

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> ***A single lifetime, even though entirely devoted to the sky, would not be enough for the study of so vast a subject. A time will come when our descendants will be amazed that we did not know things that are so plain to them.***
>
> ***— Seneca, 1st Century Roman Philosopher***

Introduction

Purpose

The United States (U.S.) aircraft industry, also known as the Aerospace and Defense (A&D) industry, is a Department of Defense (DoD) and National Security (NS) asset. This research explores the importance of the A&D industry. The influence of U.S. government policy and regulation intended to protect and sustain the domestic A&D industry are counterbalanced with federal budget constraints and technology transfer concerns. Specific areas influencing the A&D industry include the balance between export control regulation and industry fiscal health, the implications to domestic defense competition when considering affordability, and the bolstering of the global supply chain in order to preserve U.S. NS interests. To improve the U.S. position in these areas, this paper examines the need for the U.S. to inculcate innovation in the A&D industry. Additionally, the U.S. must continue to reform export control regulations while balancing national security and economic growth opportunities through trade and exports. Finally, the U.S. must confront the challenges of an aging workforce, cyber security, and an increasingly fragile supply chain. A concerted effort on all fronts will ensure a viable A&D industry capable of generating economic growth and meeting security challenges of the 21st century.

Methodology. The Eisenhower School Aircraft Industry Study team applied the Commandant's industry studies analytic framework[1] to a business model assessment informed by guest speaker presentations, site visits, and individual research assessments on the A&D industry. Research on special topical areas offer assessments of the A&D industry outlook while challenges present leaders and law makers with opportunities for policy recommendations to strengthen and sustain the A&D industry through increasingly tight fiscal constraints.

Economic Overview

In 1944, at the height of conflict in World War II, the U.S. spent $125.6M on national defense, representing a staggering 35.3% of the Gross Domestic Product (GDP).[2] Through the Cold War, U.S. spending on defense rarely strayed outside of 5-10% of GDP. In 1971, federal budgets shifted to include additional social and economic programming. Twenty years later at the end of the Cold War, defense budgets fell to the range of 3-5% of GDP, as Americans expected to reap a peace dividend with the fall of the Soviet Union. In 1993 Secretary of Defense Les Aspin delivered a clear message to defense industry executives at the famed "Last Supper" – there was not enough business to go around and barring significant consolidation many firms would face bankruptcy.[3] Leaping ahead another twenty years, the Budget Control Act (BCA) enacted fiscal constraints impacting all sectors of the Defense Industrial Complex, including the A&D industry. A graphic depicting these events longitudinally appears at Table 1.

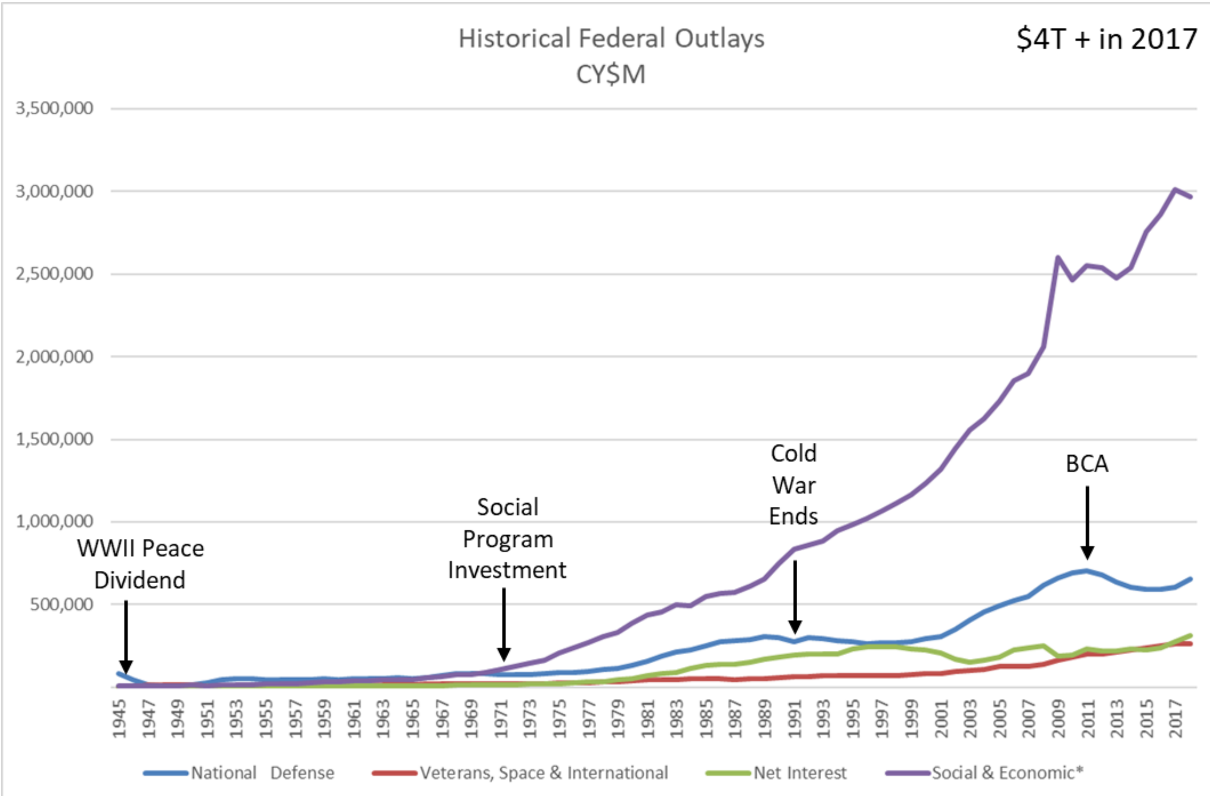

Table 1. Historical Federal Outlays 1945-2017[4]

In 2017, spending on national defense, veterans, space and international programs and net interest shared roughly 25% of U.S. outlays, while social and economic spending accounts for over 74%. Economic projections show this trend continuing, with increasing non-discretionary spending and the cost of servicing the federal debt crowding out discretionary spending, including national defense. The U.S. is the global leader in A&D defense industry research, development and acquisition (RDA) for new platforms and modernization of existing capabilities. Economic efficiencies already realized within the A&D industry have shifted to the point of creating economic dependencies by market segmentation. With projections of reduced U.S. government discretionary spending, and resulting smaller defense budgets, the A&D industry will be challenged with reduced U.S. government demand for new platforms.

Three firms have emerged as the core of the A&D industry as prime and subcontractors for military capabilities, expanding opportunities to smaller U.S. based and international organizations, and safeguarding the A&D industry. Mergers and acquisitions (M&A), joint ventures (JV), and other business alliances enhance global integration, acting as a means to expand value chains for each firm to maintain a viable industrial base for U.S. NS purposes. Collaborative RDA programs and Foreign Military Sales (FMS) are a crucial part of firm fiscal health.

The economic challenges for the U.S. have impacted, and will continue to impact, the A&D industry and how much NS U.S. leaders can provide for the common defense. In 2018 the U.S. military was allocated roughly $134.7 billion of RDA, with $35 billion identified for aircraft procurement.[5] Although $35B is a significant investment for procurement, it represents less than half of a percent (0.5%) of the U.S. GDP. A graphic presenting the RDA funding for each Service appears in Figure 1 at Appendix A.

Innovation. As stated in the NSS, "Economic security is national security."[6] The economic strength of the A&D industry with its contribution to national defense represents the hallmark of American excellence. The A&D industry has a rich history of creating innovative, highly technological programs that have significantly contributed to the U.S.'s economic, technological and military dominance. Examples include the U-2 High-Altitude Reconnaissance Aircraft, F-117 Nighthawk Stealth Attack Aircraft, Unmanned Aerial Systems and the F-35 Joint Strike Fighter. All of these platforms had revolutionary technologies revealed through their development, with implications for application in the military and private sectors. Through achievements in materials, manufacturing processes, and control systems adopted by other industries, benefits are passed on to U.S. citizens which contribute to American economic security.[7] The high-level of cooperation between government, industry, and academia, known as the triple helix, deepens the industry's ties to American society.

Exports. In 2017, U.S. defense exports totaled $20 billion.[8] This amount includes $14 billion in Defense Aerospace exports and $6 billion in Defense Non-Aerospace exports.[9] Figure 2 in Appendix B, U.S. Defense Exports, illustrates the economic influence of U.S. exports from 2007 – 2017 which represents a 5.7% Compound Annual Growth Rate.[10] Exploring another layer of economic impact, Figure 3 in Appendix C, U.S. Exports, Imports and Balance of Trade compares exports and imports for 2005 – 2017 for Civil Aerospace, Military Aerospace, and Military Non-Aerospace.[11] The comparison highlights the consistent trade imbalance for each of these export categories, which totaled nearly $86 billion in 2017.[12] Examining yet another layer of economic effects, Figure 4 in Appendix D, U.S. Exports of Aerospace Products depicts 2012 – 2017 exports for civil and military aerospace products.[13] In 2017, the U.S. exported $2.4 billion in Complete Aircraft, $667 million in Aircraft Engines, and close to $7.8 billion in Aircraft and Engine Parts within Military Aerospace, which underscores the positive economic impact to the U.S. industrial base.[14] The U.S. government agencies overseeing the trade and export processes, to include Congress, have a fundamental responsibility and crucial role to protect the economic strength and viability of the U.S. aircraft industry, and the U.S. A&D industry as a whole.

A&D Industrial Base Defined

The aircraft industry is divided into two sectors, commercial and defense. The commercial aircraft industry is dominated by two major firms: Boeing and Airbus. Domestically, defense industry front runners include Boeing, Lockheed Martin, and Northrop Grumman. The A&D industry in this research includes commercial narrow and wide body fixed wing aircraft; defense fixed wing fighter, tanker, and bomber production; and both commercial and military component, system and assembly partners. For the purposes of this research, the A&D industry does not include rotary wing aircraft, regional jets, business jets, unmanned aircraft, drones, or general aviation.

Government Goals and Roles

Export Controls

The U.S. government must continue to reform export control regulations to strike a balance between fostering domestic economic prosperity and maintaining national security. The statutory laws for export controls are the Export Administration Act (EAA) of 1979 and the Arms Export Control Act (AECA) of 1976.[15] The EAA "was the underlying statutory authority for dual-use export controls."[16] The Act is "to provide authority to regulate exports, to improve the efficiency of export regulation, and to minimize interference with the ability to engage in commerce."[17] The Act expired in 2001, but has been reauthorized and "continued by a presidential declaration of a national emergency and the invocation of the International Emergency Economic Powers Act."[18] The Act authorizes the Export Administration Regulations (EAR).[19] The AECA "provides the President with the statutory authority to control the export of defense articles and services,"[20] which include the FMS and Direct Commercial Sales (DCS) programs.[21]

Export controls represent interrelated and complex processes and procedures involving several U.S. government agencies. These include the Department of Commerce, Bureau of Industry and Security (BIS); the Department of State, the Directorate of Defense Trade Controls (DDTC); the Department of the Treasury, Office of Foreign Assets Control (OFAC); the Department of Defense, Defense Security Cooperation Agency (DSCA); and the Department of Justice (DOJ), Counterintelligence and Export Control Section (CES).

Government agencies conduct end-use monitoring to ensure export control program compliance. The Department of State performs Blue Lantern monitoring for "[DCS] of United States Munitions List (USML) articles, technology, services, and brokering."[22] The Department of Commerce conducts End-Use Checks monitoring for "Dual-use items and munitions on the Commerce Control List (CCL)."[23] The Department of Defense conducts Golden Sentry monitoring for "[FMS] of defense articles and services via government-to-government channels."[24] These programs provide a robust capability to deter and detect program violations in the interest of protecting our intellectual property, manufacturing capabilities, and national security.

Informal discussions with A&D industry officials identified several export control-related issues while criticizing the current bureaucratic processes. They indicated that although the restrictions were eased over the last two years, the approval and licensing processes still takes too long.[25] Observations of government staff in the licensing process included inconsistent application of rules, the staff appeared overwhelmed, and that staff lacked product-specific knowledge and experience.[26] A&D industry officials explained that the interagency bureaucracy hinders the process of doing business, which is exacerbated by complex rules, outdated rules, and (in some cases) unwritten rules.[27] Recurring export control reforms are necessary in the dynamic, global environment to overcome barriers to U.S. trade, promote economic growth, leverage commercially available technology, and ensure manufacturing resilience of the A&D industry. Export challenges will continue to grow as the industry grapples with globalization and its effects on competition.

The U.S.' recent decision to withdraw from the Iran nuclear agreement is problematic, but instructive from a national-level policy perspective. When the Joint Comprehensive Plan of Action (JCPOA) was signed in 2015, aerospace firms capitalized on Iran's commercial fleet demand.[28] Now that the JCPOA is void, at least from the U.S.' perspective, Boeing stands to lose $20 billion for the 100 total aircraft they planned to produce for Iran Air and Aseman Airlines.[29] The precarious, conditions-based JCPOA is an example of conflicting U.S. national-level interests and policies meant to ensure national security, stimulate trade (with an appropriate blend of sanctions, tariffs, and quotas), build a resilient industrial base, and foster economic growth.

Current Conditions

Firms competing in the commercial sector include Boeing, Airbus, Embraer, and Bombardier. Boeing and Airbus dominate the commercial market for passenger aircraft; their production of aircraft with seating for 140 and more passengers represents nearly 100% of total fixed-wing worldwide sales in 2017.[30] The A&D defense industry includes six major firms across the globe integrating parts and components from sub-tier contractors. Three of the six major firms reside within the CONUS, each covering a unique segment of defense market RDA demand. The three major segments of the fixed-wing A&D industry include fighter aircraft, tankers, and bombers.

Major Commercial Firms

Airbus, headquartered in Toulouse, France, is the second largest corporate producer of passenger aircraft. The organization is broken into four Divisions; Airbus Commercial, Helicopters, Space, and Defense. The firm is the product of international consolidation in the European A&D industry tracing its roots to the formation of the *Airbus Industry GIE* consortium in 1970. In 2000, Airbus established the European Aeronautic Defense and Space Company (EADS) NV. In addition to other subsidiaries pertaining to security and space activities, EADS owns 100% of the pre-existing Eurocopter SA, established in 1992, as well as 80% of Airbus Industry GIE. In 2001, Airbus Industry GIE was reorganized as Airbus SAS, a simplified joint-stock company. In 2006, EADS acquired British Aerospace Systems (BAE) Systems' remaining 20% of Airbus. EADS NV was renamed Airbus Group NV and SE in 2014, and 2015, respectively. Due to the dominance of the Airbus SAS division within Airbus Group SE, these parent and subsidiary companies merged in January 2017, keeping the name of the parent company. The company was given its present name in April 2017.[31]

Boeing, Airbus' principle competitor, exerts pressure by achieving greater fuel-efficiency and longer-range aircraft models. In contrast, Airbus reduces cost by relying on a large and global supply chain of more than 12,000 suppliers with major companies like Honeywell, Rolls Royce, and 3M in their value chain.[32] The extensive value chain minimizes the impact of switching costs. Airbus spans the globe with product lines extending beyond the A&D industry into other defense and commercial markets as well.

Airbus enjoys a global footprint and uses their position in commercial aircraft as their center of gravity. Commercial aircraft sales comprise 77% of the firm's business. Remaining business segments include Defense and Space making up 16% of the corporation, and the Helicopters Division representing 7% of the organization.[33] Market presence and projections remain strong for the Airbus commercial fleet, led by a shift to capitalize on the Asia-Pacific region.

Airbus is shifting its focus eastward toward the expanding Chinese, Thai, Indonesian, Filipino, Malaysian, and Indian markets. This shift overwhelmed its manufacturing capacity and resulted in a significant production backlog. While the new customer base led to a surplus of aircraft orders, it also placed a heavy demand for more efficient, technically sophisticated aircraft. Customer demand offered a means for firms like Bombardier and Embraer to capture some of the market from Airbus' order backlog. Customer choice opens more options for aircraft consumers, forcing both Airbus and Boeing to invest more toward Internal Research and Development (IRAD) to continue to stay at the top. This has caused consternation for Airbus as they "are pairing with smaller regional rivals to add sales at the lower end of the $100 billion-a-year commercial plane duopoly …[while] also laying the foundation for a longer-term strategic contest against more powerful threats such as China."[34] This challenging environment is similar for Boeing on the other side of the duopoly relationship.

Boeing. William Boeing founded Pacific Aero Products in 1916, which became the Boeing Airplane Company within a year. Eleven years later the firm completed its first M&A with

Transport Corp, becoming United Aircraft and Transportation Corp. Six years following the merger, the corporation was declared a monopoly and was split up by government order into United Aircraft, Boeing Airplane and United Air Lines. Thirty-two years passed before the corporation, now known as Boeing, would conduct any further corporate M&A or other alliances.

Boeing enjoys a global brand image and the world-leading position in commercial aircraft production which comprises of 61% of the firm's business. Remaining business segments include Defense, Space and Security making up 23% of the corporation, Global Services representing 16% of the organization, and a meager 1% in Capital Corporation which is targeted for potential divestiture.[35] Market presence and projections remain strong for the Boeing commercial fleet, led by growing demand for the recent 787 Dreamliner transcontinental passenger aircraft and ability to deliver aircraft to meet worldwide growing demand.

Boeing's corporate revenue from the last decade exceeded Airbus sales by $35 billion.[36] However, forecasts for 2018 to 2027 project Airbus will outpace Boeing in passenger aircraft sales by as much as $60 billion, based on Chinese efforts to establish and maintain a global presence in the commercial travel sector of the commercial aviation industry and a growing middle class.[37] Opportunities exist for Boeing to stay ahead as a 'first mover forward' with innovative advances in advanced manufacturing of the 787 production line and potential expansion of Boeing Global Services.

Commercial Summary

The commercial duopoly acts as a substantial barrier to new entrants in A&D production within the U.S. and around the globe. Commercial airline customers seeking to purchase new aircraft are limited to the two firms, with options to select one over the other with variables including cost, production backlog, fuel economy ~~or~~ and other desired attributes to meet commercial traveler demands. Within the U.S., Boeing has the advantage of brand identity and high demand the new 787 Dreamliner.

Major Defense Firms

Airbus Defense is a global leader in the defense sector, is the largest defense supplier in Europe and among the top 10 defense companies worldwide. With its presence in 35 countries, the company's business unit employs 40,000 people from 86 nationalities and contributes to 21% of Airbus revenues.[38] The firm manufactures tactical and strategic airlifters, multi-role aerial tankers and advanced combat aircraft. Together, the A400M, C295, CN235, A330 MRTT and Eurofighter Typhoon make up a world-class product line operated by air forces worldwide.

In addition to designing, developing, and manufacturing military aircraft, Airbus offers a broad range of services to fully support its customers.[39] Defense plays a key role for Airbus as a company. An Airbus withdrawal from the defense market would significantly impact the overall health of the company and the European Union, and result in reduced competition due to the multi-State organization and production within company. The Defense sector is so important that Dirk Hoke, CEO of Airbus Defense stated, "I am convinced that guaranteeing Europe's security requires a strong joint effort by its member states."[40] This joint effort is clearly targeting competition with the US defense sector. Particularly with Boeing, Lockheed Martin, and to a lesser extent, Northrop Grumman.

The Eurofighter began as an international program to develop a new European multi-functional fighter with the participation of Britain, Germany, Italy, Spain and France. France later withdrew, so the project was de-scoped to create a simplified fighter EF-2000. Production of components and assembly occurs on four assembly lines located in Germany, Britain, Italy and

Spain. While most of the NATO countries in Europe are armed with U.S. aircraft, they also attempt in parallel to create their own aircraft similar to the "Eurofighter."[41] With decades of industrial experience behind it to contribute to competitive systems like the Eurofighter Typhoon, Airbus consistently develops cutting-edge technologies for the most challenging missions.

Boeing Defense, Space and Security (BDS) is the defense business unit of the Boeing Company, providing multi-national defense products and solutions. The BDS contribution to the A&D industry includes multiple variants of fixed and rotary wing aircraft with significant product line changes occurring in recent years. A table presenting BDS military aircraft sales for the last 20 years appears at Figure 5 in Appendix E.

BDS, while only one segment of the Boeing Company, is essential for the long-term financial health of the corporation. Since the late 1990's there have been four years where military aircraft sustained profitability for the firm. Military aircraft procurements assist during lean years by hedging against global economic uncertainty, as evidenced in 1988, 2004 and 2009 (see Table 2). However, in 2003, BDS sales alone carried the firm through a year of significant commercial risk, avoiding half a billion dollars in losses and the risk of bankruptcy. While BDS managed to keep Boeing commercial afloat, there were also challenging years for BDS.

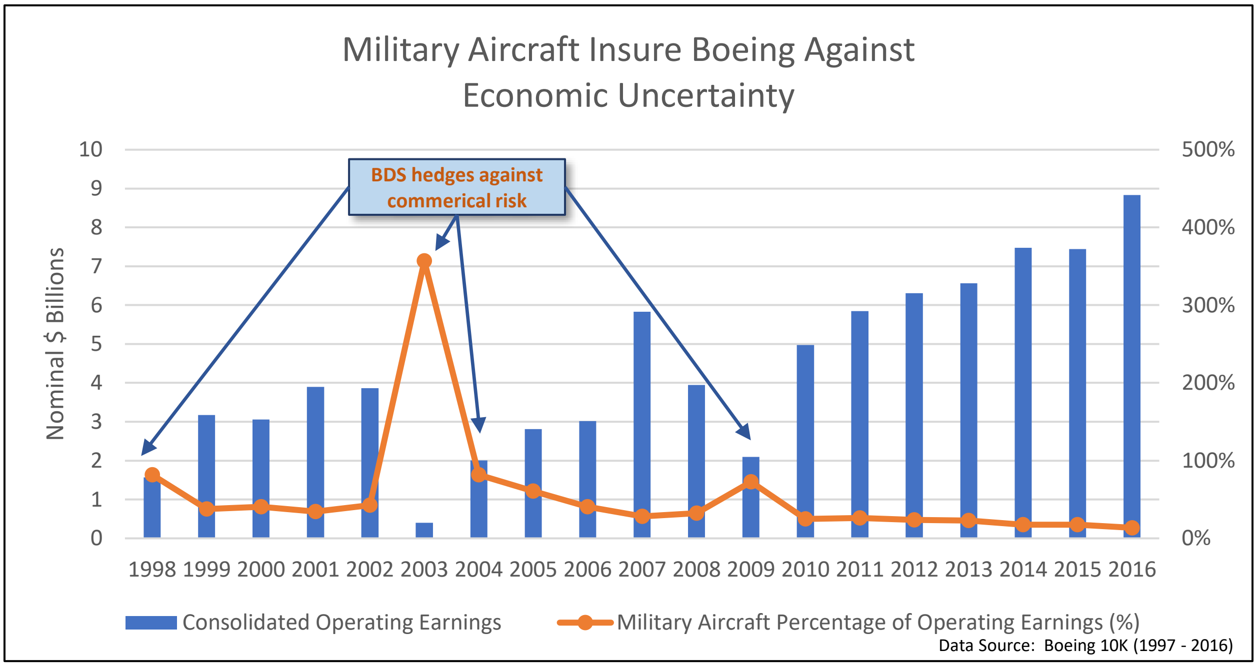

Table 2. Boeing Military Aircraft Hedge Against Commercial Risk[42]

2015 was particularly trying for BDS as it saw the closure of the Long Beach C-17 production line and failure to secure the Long-Range Strike Bomber contract.[43] In 2016, the State Department's approval of F-15 sales to Qatar and F/A-18E/F sales to Kuwait, worth $21 billion and $10 billion respectively, provided some relief.[44] These FMS sales served to buy BDS time, by extending fighter line production schedules into the 2020's. Projections for BDS FMS aircraft appear in Figure 6 in Appendix E. Barring additional contracts, however, the additional time will not close the gap that remains until the anticipated late-2020's startup of the 6th Generation U.S. Air Force (USAF) F-X Penetrating Counter Air and the Navy F/A-XX.[45] The ongoing USAF T-X trainer competition, however, offers a potential opportunity for Boeing to prevent a gap in fighter production.

Maintaining an active fighter production line for BDS is dependent upon winning the USAF T-X trainer contract which will likely be announced in mid-2018.[46] The $16 billion T-X program replaces 431 existing T-38 Talons with 350 new aircraft, which will begin delivery in 2023.[47] The trainer, touted by Boeing as a 5th Generation clean sheet design, employs a team of approximately 1,800 engineers, systems integrators, production managers, and skilled laborers.[48] The JV represents a partnership with Saab, responsible for building the center fuselage,[49] and for the Texas-based Triumph Group, Inc to supply the wing, vertical tail, and horizontal tail.[50] BDS will complete final assembly and conduct overall systems integration. If BDS wins the contract, the firm will be better positioned to maintain the talent required to compete for the next fighter.

Lockheed Martin was a founding member of the U.S. aircraft industry. Their origins date back to August 16, 1912 when Glenn L. Martin established the Glenn L. Martin Company in Los Angeles, California. Four months later Allan and Malcolm Lockheed founded the Alco Hydro-Aeroplane Company in December, which was later renamed the Lockheed Aircraft Company.[51] The two companies merged in 1955, to what is now known as the Lockheed Martin Company. Despite humble beginnings, the company now commands the designation as the largest defense contractor in the world, employing over 100,000 employees[52] with net sales of $51 billion in 2017[53] (of which, 30% were from international customers, mainly due to deliveries of F-35s[54]).

Lockheed Martin is organized "in four business segments: Aeronautics, Missiles and Fire Control (MFC), Rotary and Mission Systems (RMS), and Space, previously known as Space Systems."[55] A fifth segment, Infrastructure Systems & Global Business Solutions was spun off in 2015, to ensure it could stay in "markets where it can differentiate itself with its technology and not with pricing."[56] This divestiture allowed for the acquisition of Sikorsky Aircraft in 2015. The summation of these acquisitions and divestitures resulted in a portfolio that was squarely focused on defense products and support. Aeronautics generated $20.1 billion in sales in 2017, accounting for 39% of the company's total net sales.[57] The Aeronautics segment can credit much of this to the global F-35 program.

The F-35, a sixty-year program costing more than $1 trillion,[58] is expected to generate as much as 60% of the company's net sales.[59] In 2017, Lockheed's sales were twice as much as their closest competitor, Boeing Defense Systems.[60] Lockheed Martin benefits from reduced competition in the A&D industry, an industry that in 1980 had over 50 companies compared to the 4-5 remaining today.[61] When the F-35 reaches full rate production, that production will command 5 cents of every defense dollar spent from the base budget. Lockheed Martin could see up to 14 cents of every base defense dollar spent on their products.

Like Boeing, Lockheed Martin is also trying to capture the relatively lucrative trainer market through the USAF T-X program. Lockheed Martin is currently a finalist in the source selection process by the USAF for the T-X. The Lockheed Martin proposal hinges on a product with a known pedigree, the T-50A. The T-50A is a partnership between Lockheed Martin and Korea Aerospace Industries (KAI).[62] The aircraft is based on the single-engine FA-50, a KAI-built fighter currently in service with the Republic of Korea.[63] Jane's Defense states the T-50A "still has to prove its synthetic training capabilities, but otherwise it looks the complete package."[64] One aspect that adds to this "complete package" is the fact Lockheed is the company responsible for the F-35 Joint Strike Fighter and F-22 (5th generation fighters for which this trainer is required). The T-50 is a proven, albeit dated, platform. In addition to its fighter pedigree, it is being used in several countries now as a trainer.[65]

Northrop Grumman, like almost all the major defense firms, has a long history of providing platforms and systems for the U.S. military with business lines that stem from multiple M&As. The original Northrop Aircraft company was founded in 1938 and produced its first combat aircraft for the U.S. during World War II. Focused on designing innovative aircraft, Northrop's legacy includes the successful development and delivery of the B-2 stealth bomber. The Grumman company, founded in 1930 in an abandoned auto garage, found its niche in building aircraft for the Navy. Focusing on carrier-based fighters and attack aircraft, Grumman developed the F6 Hellcat in World War II, the A-6 Intruder, and the F-14 Tomcat of *Top Gun* fame.[66] In 1994, with the Cold War over and defense budgets rapidly falling, Northrop and Grumman merged.[67] Today, the Northrop Grumman Corporation separates its business into three sectors: Aerospace Systems, Mission Systems, and Technology Services.

In 2017 revenue was evenly split between the Aerospace ($11.9 billion, or 41.9%) and Mission Systems ($11.4 billion, or 39.9%) sector, with the third sector of Technology Services bringing in $4.7 billion, or 18.2%, each with profit margins in the range of 10-13%. A substantial increase in long-term debt in 2017 can be attributed to the company's acquisition of Orbital ATK, a company that will expand Northrop Grumman's space portfolio. The acquisition, expected to be complete in the summer of 2018, will form a fourth business line referred to as Innovation Systems.[68]

The awarding of the LSRB contract in 2015, now known as the B-21 Raider, was a pivotal moment for Northrop Grumman. If the firm failed to win that competition, its future as a prime manufacturer and systems integrator was very much in doubt. Although Northrop Grumman was a significant contributor of sub-systems and components for multiple aircraft, including the F-35, the only aircraft the company served as the prime contractor for was the E-2 Hawkeye. The LSRB contract, which is expected to produce 100 aircraft and be worth $55 billion over the life of the platform, solidified Northrop Grumman's position as a prime contractor for manned combat aircraft for the foreseeable future.[69]

Defense Industry Summary

The A&D industry is currently in a delicate balance between sustaining a viable breadth of manufacturing providers and obtaining cost affordable aircraft under existing and forecasted budget limitations. To successfully maintain this balance, continuous vigilance and hard policy decisions will be required of DoD and Congress to ensure the U.S. A&D industry remains available to meet defense requirements. The long-term outlook presents concerns given the existing posture of the A&D Industry and the demands for NS without top-line budget releif.

Industry Outlook

The A&D industry is projected to grow considerably in 2018, with global revenue growth of 4.1%, U.S. revenue growth of 3.7%, and growth in defense sector revenues of 3.6%.[70] While the U.S. A&D industry shows significant strength in 2018, there are long-term challenges that make continued industry vitality uncertain. The A&D industry must address issues that can limit innovation (including human capital, R&D investment and competition) and the ability to export products in support of U.S. interests.

Export Controls

The outlook for export controls hinges on many factors such as the degree of U.S. protectionism, willingness of the U.S. government to reduce trade barriers, and arms export trends as described below:

Protectionism. The European Union (EU), with many valued U.S. trading partners, and the United Kingdom (UK), are attempting to negotiate permanent exemptions for tariffs and quotas on U.S. imports of aluminum and steel imports.[71] If the tariffs take hold, the U.S. protectionist trade policies could backfire and counteract potential cost savings and efficiencies for the U.S. A&D industry. Tariffs could artificially inflate the cost of industrial material needed for U.S. manufacturing. The increased costs are passed on in the selling price of finished products, which may include exports to the EU. Protectionist trade policies offer little value when the policies lead to cost increases, inefficiencies, and economically-induced animosity.

Trade Barriers. The DoD's Defense Security Cooperation Agency (DSCA) is reducing the FMS surcharge by .3%.[72] The DCSA news release explains that "the rate reduction will allow the United States to become more competitive in the global defense marketplace, supporting the administration's objectives under the new Conventional Arms Transfer Policy to promote more transfers of defense arms and services to our foreign partners."[73] This reduction is an example of the Trump Administration's pledge to reduce barriers to trade, specifically for military equipment exports as prescribed in the President's 2017 National Security Strategy (NSS).[74]

Arms Export Trends. As depicted in Appendix F Figure 7, the five largest arms exporters over the last 10 years (2008 – 2017) were the U.S., Russia, France, Germany, and China.[75] Diplomatic and economic leverage are essential instruments of power commonly wielded through security cooperation and export control policies. SIPRI reports that "[a]rms transfers are often used as a U.S. foreign policy tool to forge new strategic partnerships."[76] An example of strengthening partnerships through arms transfers is the increase in defense exports from the U.S. to India and Vietnam "to offset China's growing influence in Asia and Oceania."[77] Another case in point is the surge in arms exports from the U.S. to Saudi Arabia which bolsters the country's capabilities against regional aggressors such as Iran and violent extremists.[78]

A recent trend report states that "[w]e may also see new efforts to streamline the approval process of the FMS system, including potentially eliminating important checks to ensure U.S. arms are not illegally diverted."[79] The report cautions that "there is a strong chance that the Trump Administration will greatly increase the number of U.S. arms sales notifications in 2018 with less oversight."[80] While easing the arms exports checks and balances (i.e., oversight) may result in an economic windfall for the U.S. (and reduce the trade deficit in the process), the long-term impact to U.S. relationships with its allies and friends are not inconsequential. While the U.S. is keen to realize the economic benefits of increased exports, the U.S. must use restraint to avoid undermining the valuable cooperative relationships with trusted partners.

Deloitte predicts that "[a]s global tensions rise, defense spending growth is likely to continue over the next five years"[81] and estimates that "global defense spending is anticipated to grow at a CAGR of about 3.0 percent over the 2017–2022 period, crossing U.S.$2 trillion by 2022."[82] This sizeable growth in the global defense market offers an opportunity for the U.S. A&D industry to expand on its market share and further contribute to building stable relationships with security partners.

Defense Competition.

The Department of Defense (DoD) uses competition within the industrial base to its advantage—improving capability while controlling costs. Since the conclusion of the Cold War, competition has become more difficult to attain due to industry consolidation and governmental monolithic programming. Today, nine major defense contractors remain in the U.S. with significant contributions to the A&D industry which include: Boeing, Lockheed Martin, Northrup Grumman, General Electric, United Technologies, Honeywell, Rockwell Collins, Raytheon, and L-3 Communications.

The nine firms are segmented into three categories: integrators/final assemblers, engine manufacturers, and mission systems manufacturers. Two firms represent the existing five military fixed wing purpose built final production lines in the U.S. today. Lockheed Martin's F-35 Lightning II, F-16 Falcon, C-130J Hercules and Boeing's F-15 Eagle and F/A-18E/F/G Super Hornet/Growler are the active lines currently producing military unique combat aircraft. Northrup Grumman is projected to begin producing the B-21 Raider (LSRB) in the 2020s, which would reslt in a sixth production line. However, Lockheed's F-16 and Boeing's F-15 and F-18 lines are at risk of closing in the mid-2020s without additional contracts to produce their respective fighter aircraft. General Electric and United Technologies' subsidiary, Pratt and Whitney, are the two engine manufacturers. Honeywell, Rockwell Collins, Raytheon, and L-3 Communications provide mission systems such as radar, communications gear, electro-magnetic warfare equipment and other purpose-built systems for military unique applications.

Industrial base sustainment through the lean years following the Cold War included creative workshare measures aimed to maintain the viability of firms, leverage firm expertise, and secure both domestic and international contracts for prime contractor integrators. The F-35 is a complex program in which Lockheed Martin, as the prime contractor, oversees final assembly but depends heavily upon Northrop Grumman and BAE Systems for major portions of the overall production. Northrup Grumman produces the center fuselage and much of the unique equipment to its expertise derived from previous work on the B-2. In all, the firm is responsible for producing over 25% of the F-35, ranging from the aircraft's structure to subcomponents such as avionics and mission planning software. BAE produces the F-35's aft fuselage, horizontal tails, vertical tails, fuel system, and life support system. Excluding the propulsion system, BAE is responsible for producing 13-15% of the aircraft, depending on the variant.

Similarly, the F/A-18 and F-15 are produced by multiple vendors and assembled by Boeing. Northrup Grumman produces the F/A-18's aft/center fuselage section and twin vertical tails. Raytheon provides many of the mission systems for the aircraft to include the APG-79 active electronically scanned array (AESA) radar, targeting forward looking infrared electro-optic sensor, and numerous other provisions. The F-15, likewise, is produced by KAI of South Korea, Honeywell, Lockheed Martin, L3 Communications, Raytheon, and Rockwell Collins. Similar arrangements sustain the production of both the F-16 and C-130. Policy recommendations precede conclusions to ensure the firms which comprise the A&D industry remain competitive for future requirements.

International Competitors

Both China and Russia maintain state-owned companies, generating revenue for commercial and defense industries within their respective nations while addressing internal national security interests. China's Commercial Aircraft Corporation of China, Ltd. (COMAC) and Russia's United Aircraft Corporation (UAC) are examined as potential competitors to Boeing and Airbus. Successful competition from COMAC and/or UAC has security ramifications since both Boeing and Airbus are strengthened by deriving income from both commercial and defense sectors. Both COMAC and UAC are considered in terms of their respective country's economy, the prospects for each country's internal aircraft demand, their technology, their experience in building aircraft, and their experience supporting a modern supply chain for aircraft.

China enjoys a robust, growing economy. The Economist Intelligence Unit estimates that China's real Gross Domestic Product (GDP) will increase at an average rate of 5.9% between 2018 and 2021 with a high probability that China's economy will outperform the forecast.[83] With the second largest economy in the world (which is well on its way to being the largest economy in the world), there seems to be little reason to doubt that China would have the economic bandwidth to support a major commercial aircraft industry. Air travel in China is expected to increase in light of a growing and increasingly wealthy middle class. Chinese are not only traveling more, they are traveling more frequently "as evidenced by a rise of over 185 percent in annual domestic trips over the last decade."[84] In this context, Boeing's estimate that China will require 7240 new aircraft between 2016 and 2036 is probably reasonable.[85] It is clear that China will have a large internal aircraft market which China could leverage to mature a commercial aircraft industry before entering worldwide competition. There is much evidence that COMAC has readily available, current experience in participating in state of the art supply chains through companies that are part of COMAC.[86] The Chinese should be well aware of what the expectations are of a world-class supply chain and should have significant insight into what goes into establishing that network.

China's 2025 aircraft goal of "main-line aircraft delivery should be above 10% of the total domestic market…"[87] is worth noting. Using Boeing's estimate that China will require 7240 aircraft deliveries in the next 20 years, this goal would translate into COMAC producing about three planes per month by 2025—a goal that may also be achievable. But to ramp up from producing three aircraft per month to actually challenging Boeing, Airbus, Bombardier, and Embraer will require at least 20 years, if not more.

Russia's situation is very different from China's. Russia's GDP is not quite 13% of China's at $1,574.4 billion for 2017. GDP growth, projected to be between 1.5 and 1.8 percent through 2022 (heavily dependent on oil prices) is modest compared to China's, and GDP per capita is generally static around $25,492 (by purchasing power parity).[88]

According to D. V. Manturov, Chairman of the Board of Directors of UAC, "…the share of the Corporation's revenues from the sale of civil aircraft must grow from less than 20% in 2015 to 45% by 2035; UAC's share in the global civil aviation market must grow from less than 1% to 4.5% by 2025."[89] There is no apparent plan or source of investment for achieving these goals. It is not apparent how Russia would establish a sufficient level of production of aircraft or a system to sustain those aircraft once they are flying to make a significant difference in the market. Even if UAC managed to capture 4.5% of the global civil aviation market by 2025, that would hardly constitute a significant challenge to the major aircraft producers.

Industry Challenges

Human Capital

The primary A&D industry workforce challenges are knowledge continuity, recruitment, and ensuring the educational system continues to graduate a workforce with the right skills for the industry. The industry is preparing for a once-in-a-generation change-over in a workforce spanning five generations.[90] The bulk of the current workforce joined the industry in the mid-sixties to early seventies during the Apollo era.[91] Growing concern remains for the potential wave of retirements as these employees become eligible for retirement. Approximately 60% of workers in the A&D industry are over age 45 compared to 44% in other industries.[92] This is compounded with projected demand for A&D industry engineers to grow approximately six percent over the next ten years.[93] While the projected demand is relatively stable, the A&D industry must compete with the increasing number of other industries requiring engineering skills. Finding suitable replacements with the knowledge and expertise lost during the transition will be a challenge for the industry. While A&D continues to be home to advanced technology and big ideas, other segments of American industry have caught up. The ongoing technological breakthroughs in Silicon Valley have increased the opportunities for younger generations in the workforce, outside the A&D sector.[94] Top driving factors for working in Silicon Valley include pay and bonuses ranking near the top, with the most important factor being the opportunity to demonstrate creativity and access to the latest technology.[95] The good news for the A&D industry is young professionals entering the industry tend to remain and recommend the industry to others.[96]

Young professionals today are entering the workforce where technology and innovation change the landscape in radical ways. The number of companies and industries which can offer access to the latest technology paired with opportunities to tap into their creative side is increasing. Recent surveys have highlighted a significant shift in the views of young professionals once considered a traditional recruiting base for A&D. Most striking is the appeal of high-tech jobs outside of aerospace. These jobs offer the opportunity for young professionals to achieve an immediate sense of impact compared to A&D projects taking years to complete.[97] Since people, are still the strength of the A&D industry, firms might invest more heavily into hands-on mentorship programs with engineering students.[98]

Yet, the American technological edge is eroding[99] as a result of our competitor's aggressive pursuits to develop commercial and military capabilities in an effort to minimize America's position in the world.[100] The world's most innovative companies enable their success through the people, processes, and philosophies defining the culture of their organizations.[101] These technological feats are the product of "The Innovator's DNA"[102] considered a CEO's recipe for success when applied to companies. However, the "Innovator's DNA" is germane to America's A&D industry and contemporary national security threats. The A&D industry would have to invest 4.1% of its 2018 projected revenue[103] to meet the NSS challenge to counter this erosion. This investment would promote and protect a vital component of the U.S. National Security Innovation Base (NSIB) through research, technology, invention, and developmental processes growth.[104]

Cybersecurity.

Both the commercial and defense A&D industry sectors face cybersecurity threats. These threats are considered either devious-but-benign or deliberate.[105] Deliberate cyber-attacks present the greatest concern, with sufficient information technology (IT) sophistication to access avionics networks.[106] Where some cyber-attacks have sought after and obtained information from a specific computer, server, or network, the deliberate cyber-attacks against avionics take a different approach. The cyber-attackers are either insider, nearsider or outsider threats.[107] The attackers quite often seek to overload systems with excess amounts of input to deny services to or disable avionics systems.[108] For DoD, insiders can be military, civilian or contractor. In the commercial sector, any number of direct or contract employees could be cyber threat perpetrators and participants in corporate espionage.

Commercial and defense sectors are burdened by the additional investment of time and money cybersecurity demands to develop, deliver, maintain, and protect secure systems. The demand signal for these efforts has resulted in an entire value chain to ensure systems are protected by deterrence efforts, monitored for cybersecurity compromises, and employ appropriate defensive cybersecurity responses. However, the military is now authorized to execute offensive cybersecurity operations.[109]

Mitigating cyber security breaches and vulnerabilities to cyber-attacks begins early in the DoD acquisition process, documenting required tests in a Test and Evaluation Master Plan (TEMP) as well as operational test plans (OTPs).[110] DoD conducts a two-phased approach for cybersecurity testing, consisting of a cooperative vulnerability and penetration assessment (CVPA) followed by an adversarial assessment (AA).[111] The CVPA is an exhaustive review to identify all potential cyber vulnerabilities that could be exploited in a future capability focused primarily on insider and nearsider threats. The AA tests how the system holds up against cyber-attacks from NSA certified ethical hackers while in operation replicating outsider threats. Initial OT&E (IOT&E) and Follow-On OT&E (FOT&E) credit cybersecurity testing only when all test events are recorded in the OTP and TEMP of a system during Operational Testing (OT) phases of the acquisition cycle.[112] The Operational Test Agency (OTA) conducts a Tactical Air Vehicle System (TAVS) cyber OT&E events and issues an authority to operate.[113]

MAYHEM is a commercial-off-the-shelf (COTS) product used in DoD's Defense Innovation Unit Experimental (DIUx). MAYHEM collects binary data from operating systems on a network, identifying and isolating cybersecurity vulnerabilities, then targeting and deploying fixes overnight to cyber-harden the system.[114] Most cyber testing is conducted throughout the acquisition lifecycle on site or at the National Cyber Range (NCR)[115] with indemnification for the machine language equivalent source lines of code (ESLOC) where many cyber vulnerabilities occur.[116] Utilizing MAYHEM and the NCR is currently voluntary, written into contracts to address vendor concerns for intellectual property (IP) when DIUx cyber testing is included. The faults and fixes in the sanitized version of the software[117] are turned over to the vendor for verification, validation, modification and installation to preserve the vendor's IP. The voluntary option for NCR testing and proprietary nature of IP create friction within the program where cybersecurity is at risk. A&D industry manufacturers and avionics software providers may be patriotic but would much prefer to keep the DoD and commercial customers tied to long-term support to extend the value chain and increase profitability.[118]

Beyond testing, risk mitigation requires a strong and reliable supply chain, free of faulty equipment and counterfeit products. In the case of microelectronics, the DoD requires microelectronic supplies to be vetted through the Defense Microelectronics Activity (DMEA),[119] which manages the DoD trusted foundry program. The DMEA issues accreditation for suppliers and the supplies they produce, signaling they are free from defects and readily available to the DoD. The DMEA is the authoritative source for chain of custody validation and coordinates with industry through the Trusted Access Program Office (TAPO) for electronic and microchip procurement and supply.[120] This includes production of obsolete microelectronics from the DMEA's flexible foundry. The flexible foundry is a single facility used to execute Advanced Reconfigurable Manufacturing for Semiconductors (ARMS) made possible through partnerships with industry to transfer technology and leverage the most reliable national security resource.[121] However, continuous surveillance is reliant on honest brokers. Suppliers are expected to keep the lines operating the way in which they were certified or to report and recertify their line with the DMEA.[122]

Global Supply Chain

The reality of a globalized, lean, digital supply network presents a variety of challenges for the A&D industry. These challenges must be managed to reduce the risk of supply chain disruption. These risks include the security of supply network digital information systems, the introduction of counterfeit parts into the inventory and supply network disruptions (caused by sole suppliers or political disagreements between nations). These risks could challenge the ability of the A&D industry to quickly surge and sustain production in the event of a national security requirement. While the U.S. government and A&D industry do not directly control all these risk factors, a collaborative approach to these challenges would lead to better understanding of current supply chain risks and policy options to mitigate them.

Protection of the digital supply chain should be recognized within the A&D industry as a top priority. According to Ernst & Young, "As major A&D companies increasingly implement integrated supply chain management platforms to better manage their supplier network, any data theft or cyber-attack on any part of the platform can potentially cause a threat to the entire supply chain network, creating a multiplier effect."[123] It is clear that state and non-state actors possess the capability to attack and disrupt both government and commercial digital networks - to include supply network information systems. We already know "[a] number of states have already developed relatively sophisticated means of cyber-attack…These capabilities can be used to attack…logistics systems as well as hold at risk a variety of strategic civilian targets such as critical infrastructure and economic targets."[124] The vulnerability of a digital supply network presents significant risk to aircraft manufacturers and end users. The U.S. government should insist that A&D industry OEMs engage all critical suppliers across the entire supply network to ensure integrated, synchronized, technically capable cyber security measures are employed to ensure the security of the digital supply network information systems. Protection must also extend to the supplies in the chain and prevention of counterfeit materials.

The introduction of counterfeit parts into the A&D industry supply network represents a significant threat. Officials already confirm, "[a]lmost anything is at risk of being counterfeited, including microelectronics used in fighter jets and missile guidance systems, fasteners used in aircraft, and materials used in engine mounts."[125] This risk is exacerbated by the global nature of the supply chain, and the potential access to design and logistics data via digital networks. For the DoD, the Defense Federal Acquisition Regulation Supplement (DFARS) provides guidance to prevent the introduction of counterfeit parts into the DoD supply system. While major OEM suppliers have the resources to comply, "DFARS clauses are required to be flowed down to lower tier suppliers, so smaller contractors face a more difficult road in complying with these stringent sourcing and oversight provisions."[126] While efforts to combat the introduction of counterfeit parts into the supply chain through the DFARS and industry contract language, there is not an integrated, systematic strategy across government and industry to identify counterfeit parts and prevent their introduction into the supply chain. Government and industry must better partner to develop a comprehensive strategy to mitigate the risk presented by counterfeit parts.

Finally, both commercial and military production and sustainment networks rely on sole source suppliers for many critical parts. OEMs during industry visits reported that the sole source supplier issue is a risk to supply network security and resilience. Furthermore, the advanced age of current military aircraft fleets has resulted in ever shrinking part sources, as supplier's transition from support of aging, low-profit platforms to newer aircraft. According to a report by Ernst & Young,"…when a supply delay or quality issue occurs at the end of the sole-source supplier, it poses a greater risk in terms of production halt, delayed delivery and cost overrun."[127] OEMs are aggressively exploring supply network strategies that eliminate waste and cut cost end to end throughout the supply network. This approach produces an aerospace supply network base with little excess capacity, susceptible to disruption. It is therefore imperative that DoD and major OEM integrators understand the scope of sole source suppliers within the supply chain and the potential impact to national security. This understanding should then inform the development of acquisition policies aimed to mitigate this risk. These challenges loom large on the outlook for the industry. What also looms large is the competition from China and Russia.

China and Russia as Commercial Competitors

China has significant experience building aircraft for non-Chinese companies. As of January 2018, the joint Chinese and Airbus Final Assembly Line China (FALC) at Tianjin had assembled 354 A-320s.[128] Both Airbus and Boeing are expanding business with China. Airbus intends to open a completion plant for widebody A330s at Tianjin.[129] Likewise, Boeing is setting up a completion facility at Zhoushan in a joint venture with COMAC, to deliver up to one hundred 737 aircraft per year to Chinese airlines. The Boeing facility will be capable of aircraft maintenance which is another relevant learning opportunity for the Chinese.[130] It is clear that COMAC will have plenty of Chinese experience to drawn upon in setting up large scale production.

Among China's current products, the ARJ21 regional jet and the C919 single aisle passenger jet, use many foreign parts (e.g., U.S. or French engines), but are not particularly advanced. The ARJ21, announced in 2000, achieved first flight in 2008. A production license was not granted for the ARJ21 until 2017 and the program still not in regular production.[131] The C919 was originally supposed to be 15% composite, but that was reduced to 10%,[132] and have taken a very long time to develop. The C919 program began in 2008 with the first flight test in May 2017. Targeted dates for full rate production is unclear. Despite these domestic delays, China has found other partners to continue to bolster its aircraft industry.

China is teaming with Russia to build the Long Range Wide Body Aircraft, the CR929. Currently, initial roll-out is scheduled for 2023 with deliveries beginning in 2026—these dates already reflect slippage.[133] Given those dates and COMAC's track record of slippage, it will be a very long time before COMAC has a wide-body model to challenge Airbus or Boeing. It is very likely China is motivated to work with the Russians on the CR929 to take advantage of Russian composite technology and very possibly to expropriate technology for China. The plan is for 50% of the CR-929 to be made of composites (the same level of composite employment by weight in the Boeing 787[134])—the composite work will be done in Russia with the aluminum fuselage being made in China and final assembly being done in China.[135]

Russia's UAC has published a "Market Outlook 2017-2036" which has significant similarities to Boeing's "Current Market Outlook 2017-2036"; UAC's estimates of CIS's demand between 2017 and 2036 are very similar to Boeing's: 1140 regional and single aisle passenger jets (Boeing: 1100) and 155 wide-body jets (Boeing: 160).[136] UAC will not have nearly as large an in-country ramp-up market as COMAC.

Russia has nothing to compare with China's experience supporting modern supply chains or running world-class aircraft assembly operations. Russia produces the Sukhoi Superjet 100 regional jet and the Irkut MS-21 single aisle passenger jet. Russia has built 145 Sukhoi Superjets and current production capacity is about 30 aircraft per year.[137] Development of the MS-21 has been quite protracted, with program initiation in 2002 and first flight in May 2017. There is no indication of when the MS-21 will begin production.

The UAC "Annual Report for 2016" quotes Russian Prime Minister Dmitry Medvedev as saying, "There are very few nations that have aircraft-manufacturing industries. They represent the top league globally and we mustn't drop out of that group, so we are working for the future and we will continue to update the Russian civil aircraft fleet."[138] To his point, being able to produce commercial aircraft is a matter of pride for Russia and there is every reason to expect to see those production efforts continue, but given the lack of investment, experience, and indigenous market for ramp up, the likelihood that UAC will ever significantly challenge Boeing, Airbus, Bombardier, or Embraer is very slim at best.

Although China continues to experience delays in getting the ARJ21 and C919 into production, China will invest as necessary to get those aircraft and improved successors into production. China will find ways to obtain the technology they need. China will leverage their internal aircraft market and expertise from working with Airbus and Boeing to ramp up production and support for their products. Perhaps in twenty years, China will be able to compete internationally with Boeing, Airbus, Bombardier, and Embraer. Russia will likely remain a footnote in this discussion.

Recommendations

Export Controls

Based upon the specific focus of this research, special topics influencing the aircraft industry are addressed here in greater detail. These include the balance between export control regulations and economic growth, implications to NS interests from dwindling domestic defense competition and bolstering the global supply chain to preserve U.S. NS interests. Industry officials acknowledge there have been improvements in the export control processes; however, they are still experiencing inconsistencies and inefficiencies which cause frustration and present barriers to commerce.[139]

The export control laws, regulations, and procedures can be improved by implementing the following recommendations:

- Adaptive Export Controls. Industry, and by extension the economy, will benefit with an adaptive review process responsive to change; a process which examines aerospace products, emerging technologies, prolific mature technologies, and dual-use applicability.[140] Recurring reviews will inform updated, contemporary policies and procedures that align with the needs of an ever-changing global landscape.
- Non-Sensitive Export Items (NSEIs). Exporting NSEIs (600-series) not tied to an FMS case impedes industry.[141] NSEIs were removed from the ITAR USML during previous reforms and placed on the CCL which requires less strict monitoring. [142] Caught in a catch-22 situation, the BIS will not issue a CCL license to export the item unless the item is tied to an FMS case.[143] The Department of State and Department of Commerce should coordinate changes to the interagency rules and procedures to allow export of these products and remove the policy gap hampering export opportunities.[144]
- Program-Level Licensing. Currently, U.S. firms must obtain an export license for every major and minor part to support an end item or program.[145] Industry and their foreign customers will benefit by obtaining a long-term, program-level license.[146] A long-term, program-level license will result in efficiencies, and assure continuity and stability of the global logistics supply chain.
- Streamline Trade with Allies. The ITAR authorizes export exemptions for Canada, one of the U.S. closest allies.[147] The U.S. would realize significant benefits by applying similar

exemptions to other trusted allies, such as Australia, New Zealand, and the United Kingdom, which represent the balance of the Five Eyes intelligence alliance.[148] A logical starting point to streamline the ITAR export approvals is to conduct country-by-country risk and opportunity assessments based on the EAR's Strategic Trade Authorization (STA) license exceptions.[149] The EAR specifies 36 countries that are deemed by the U.S. as Favorable Treatment Countries.[150] The specific countries are identified in Appendix G Figure 8. Export Administration Regulations (EAR) Favorable Treatment Countries.

- Training. The U.S. government interagency coordination processes are onerous and complex. Even with new legislation, one must remain skeptical that the bureaucratic constraints will be loosened. An inherent tendency of government is to add layers of oversight and bureaucracy when instituting and enforcing regulations, policies, and procedures. However, U.S. government organizations can effect positive changes and improve interactions with their industry counterparts. Staff members of government organizations that inconsistently apply export control rules can be remedied through initial and recurring training on export control laws and procedures. Agencies responsible for implementing the policies commonly offer outreach services, seminars, and webinars to educate not only the public (i.e., traditional customers), but the myriad of other government agencies impacted by the policies and procedures.
- Human Capital. U.S. government organizations can overcome product knowledge and experience shortfalls by recruiting technology-savvy talent with program experience. Agencies should aspire to hire people with relevant experience which will mitigate the steep learning curve of the multifaceted export control domain.

Defense Competition.

Defense competition has been in decline since the early 1990s due to M&A and other consolidation activities resulting from a decrease in defense related spending. This trend is driving the industry toward a future state in which only a single firm will remain to fulfill government contracts. Competition is essential to maintain innovative and affordable aircraft within the A&D industry. To maintain this desirable goal and reverse the trend, four policy recommendations are offered below. These include foreign procurement, high-end exports to trusted partners, reexamining well intended but flawed government efficiency incentives, and maintaining a minimum of two final manufacturing contractors.

The A&D industry defense competition can be sustained by implementing the following recommendations:

- Foreign Procurement. The first policy government leaders should explore is removing the written and unwritten prohibitions on procuring some major defense platforms from foreign firms. Those platforms could be selectively competed based on the strength of competition and innovation within the U.S. domestic defense industrial base. As the U.S. defense market faces the pressure of an inevitable decline in defense spending and award contracts that can determine the entire future of a company, one way to maintain a healthy defense industrial and innovation base is to expand the pool of firms that are competing.
- High-end Exports. The second policy recommendation that the U.S. government should consider is to allow for the export of high-end systems to highly trusted allies and partners. With the F-15, F-16, and F/A-18 production lines, U.S. defense companies are able to sustain industrial base capacity and capability largely through export of these systems. For a company like Northrop Grumman, the opportunity to export a high-end platform like the

LSRB could bring resources that enable the company to retain the capability and capacity to design and manufacture combat aircraft through lean U.S. defense budgets.

- Reexamine Efficiency Incentives. The third policy recommendation is to reexamine attempts at incentivizing industry to realize efficiencies in their manufacturing processes and supply chain. As a customer the government recognizes that industry is able to find efficiencies in their manufacturing processes and supply chains the longer they produce a weapons system. But through some of its more recent initiatives (e.g., Department of Defense's Better Buying Power), the government appears to be upsetting the balance of the risk-reward relationship. In effect, the government is asking industry to accept additional risk without giving them the opportunity to profit it from it. In turn, this business practice drives industry away from doing business with the government, especially for lower tier firms that manufacture dual-use components.
- Maintain Minimum of Two Integrators. Finally, though strategic acquisition policy choices such as the F-35 create the potential to drive down procurement costs through economies of scale, this short-term gain creates the long-term potential to drive competition from the defense industrial base. Consider maintaining two separate integrators/final manufacturing contractors. Competition would be between contractors to receive the prized U.S. Air Force quantities while the second would receive the lesser volume U.S. Navy and U.S. Marine Corps orders. This policy would only be for high volume contracts such as fighter and attack aircraft. To mitigate two separate costs for development, design and testi requirements with each firm, both manufacturers would have to agree to provide technical data and specifications to the government, and both would have to commit to delivering to aircraft specifications with little to no Service unique differentiation. Lower quantity surveillance and intelligence bids would remain competitive at large.

Global Supply Chain

The ability of the A&D industry to quickly mobilize to meet increased DoD requirements during a major military contingency is in doubt. The global supply network functions relatively well during steady state operations in a stable global security environment. However, the characteristics of this global supply network present significant risks to national security requirements should mobilization be required to meet a national security challenge. A lean global supplier base linked via digital information systems results a supply network vulnerable to disruption.

The global supply chain can be sustained by implementing the following recommendations:

- Digital Information System Security. The security of the supply network digital information systems must be a priority. Voluntary standards currently published the by the National Institute of Standards and Technology (NIST) should be used as a template by a government-industry task force to develop mandatory cybersecurity standards for supply network information systems that apply across the entire A&D supply network. The cybersecurity standards for supply information systems should employ DIUx and MAYHEM to sanitize networks prior to utilization as well as at every test event throughout the acquisition lifecycle. Government and industry should collaboratively determine the appropriate mechanism (law, regulation, policy) used to document, implement, and enforce this requirement. Further, government and industry must then use the NCR DIUx output as an audit/enforcement mechanism to ensure this requirement is executed at all levels of the supply network. This is the first step to securing the vital information systems that are essential to supply network operation.

- Counterfeit Parts. Despite Defense Federal Acquisition Regulation Supplement requirements that prime contractors to have establish anti-counterfeit systems in effect at all tiers of their supply base, exactly what anti-counterfeit measures steps are required and if they will be accepted by DoD remains uncertain. The DoD must expeditiously complete the development of detailed guidance and criteria to ensure synchronized and effective anti-counterfeit systems are established to safeguard the reliability and capability of US aircraft, related equipment, and the supply network. The DoD should require utilization of trusted suppliers, to include production at TAPO authorized facilities, through the DMEA.
- Sole Source Suppliers. Sole source suppliers of critical components are a reality of the current supply network that is not fully understood. The DoD and the A&D industry do not have a comprehensive understanding of the scope of this issue. DoD should form a task force in partnership with industry to understand the scope of sole source suppliers across the A&D industry. This study should then inform the development of mitigation measures to ensure the security of the supply network during both steady state operations and to meet ramped up demand during national security contingencies.

Conclusion

The U.S. is the global leader in A&D defense industry research, development and acquisition (RDA) for new platforms and modernization of existing capabilities. The U.S. government has an inherent responsibility to promote U.S. industrial capabilities and sustain the industrial base. Recurring export control reforms are necessary in the dynamic, global environment to overcome barriers to U.S. trade, promote economic growth, leverage commercially available technology, and ensure manufacturing resilience of the U.S. industrial base. The U.S. export controls must be continuously reviewed and adjusted to remain viable, practical, and in our nation's interests. The U.S. must continue to reform export control regulations while balancing our national security and economic growth opportunities through trade and exports.

Increased defense competition is essential to maintain innovative and affordable aircraft within the A&D industry. Permitting trusted foreign A&D industry firms to participate in the U.S. defense market for major weapons systems will help spur innovation and build shared capacity across the A&D industry. Allowing high-end weapon systems to be exported to highly trusted allies will expand partnerships and sustain the domestic A&D industry. Acquisition strategies that maintain a minimum of two final manufacturing contractors ensure the U.S. remains capable of meeting surge capacities, provided technical data is shared and duplicate costs for both lines are affordable. One balancing mechanism is to articulate acknowledgement that A&D industry firms have achieved maximum efficiency, paving the way to re-examine efficiency incentives.

Mitigating risks to the global supply chain due to cybersecurity and during mobilization are central to U.S. NS priorities. Government utilization of DIUx from COTS capabilities to ensure secure networks and information systems remain free of vulnerabilities is achievable through policy and regulation. Maximizing trusted sources including the DMEA's trusted supplier lists and trusted foundries ensures a ready supply remains available, mitigating the impact of counterfeit items in the supply chain. Validating sole source suppliers within the U.S. to ensure the A&D industry has a full appreciation of the impact suppliers have on the value chain is also critical to success.

The re-organization of the Office of the Under Secretary of Defense for Acquisitions, Technology, and Logistics (AT&L) was directed to facilitate the speedy development of products and a “culture of innovation” in the highest levels of the DoD.[151] But reform alone will not bring about the changes needed to address long-term threats to the A&D industry. Meeting U.S. NS interests identified int his research lead us to the conclusion that we must guarantee a viable A&D industry stands ready to provide capabilities to meet NS requirements to provide for the common defense. It will take the concerted efforts of senior military leaders, lawmakers, and firms to ensure the U.S. maintains vital NS interests in the A&D industry as a NS asset to strengthen and sustain the A&D industry through increasingly tight fiscal constraints.

APPENDIX A
FY2018 Military RDA by Service

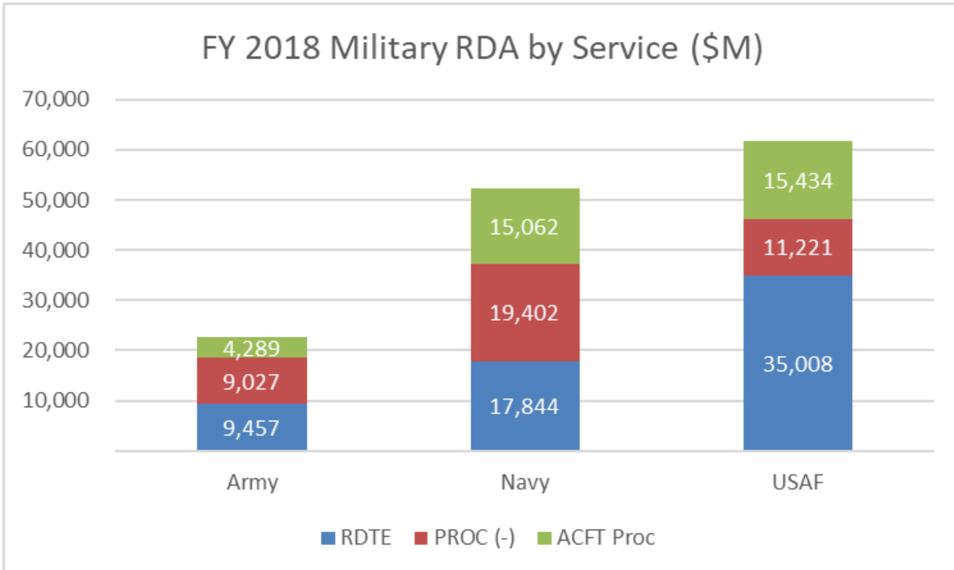

Figure 1. FY2018 President's Budget Request for Military RDA by Service[152]
Total U.S. military RDA is $134.7 billion of RDA, with $35 billion identified for aircraft procurement, representing less than half of a percent (0.5%) of the U.S. GDP.

APPENDIX B
U.S. DEFENSE EXPORTS

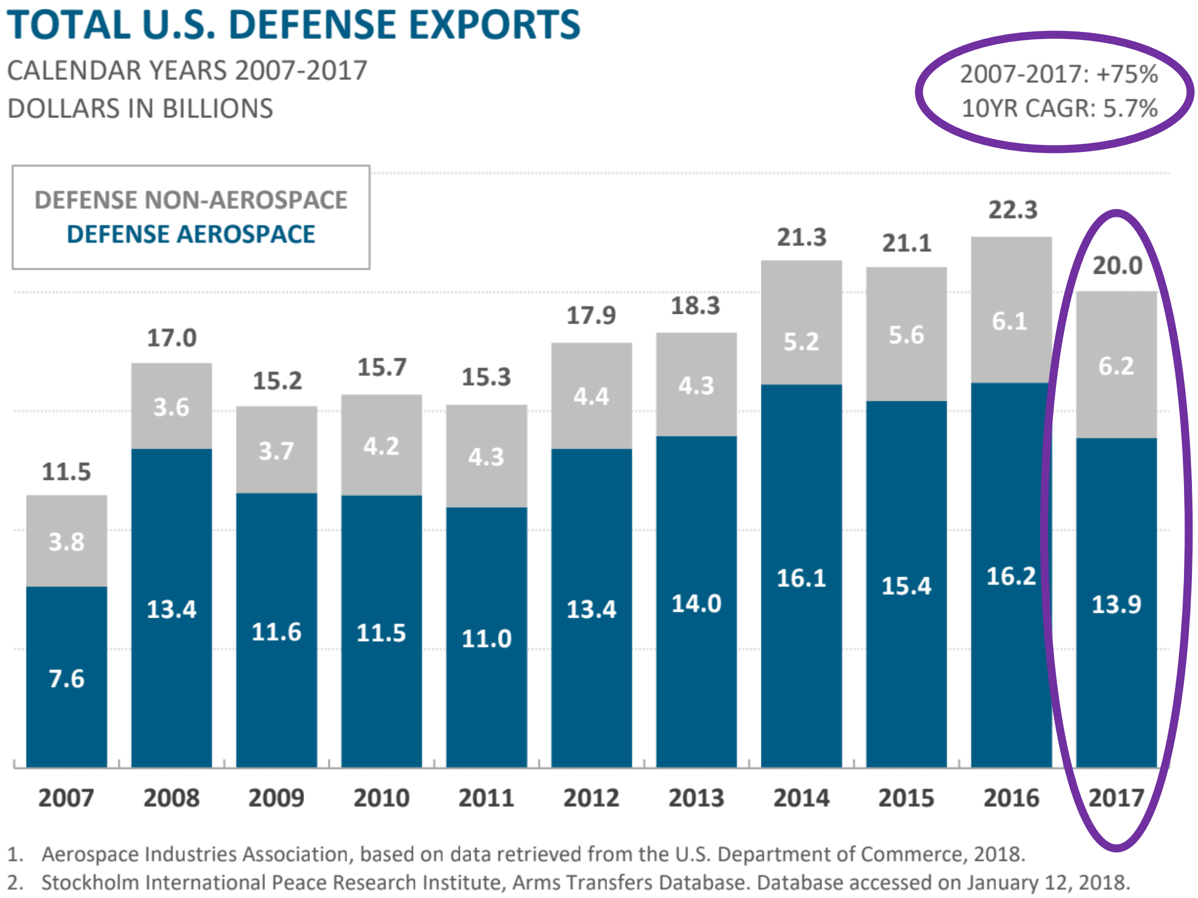

Figure 2. U.S. Defense Exports. In 2017, U.S. defense exports totaled $20 billion with $14 billion in Defense Aerospace industry exports and $6 billion in Defense Non-Aerospace exports. U.S. exports from 2007 – 2017 represents a 5.7% Compound Annual Growth Rate (CAGR).[153]

APPENDIX C
U.S. AEROSPACE AND DEFENSE
EXPORTS, IMPORTS AND BALANCE OF TRADE

EXPORTS, IMPORTS, AND BALANCE OF TRADE:
U.S. AEROSPACE AND DEFENSE

Calendar Years 2005-2017
(In Millions of Dollars)

AEROSPACE INDUSTRIES ASSOCIATION

Year	Balance	Exports				Imports			
		Total	Civil Aerospace	Military Aerospace	Military Non-Aerospace	Total	Civil Aerospace	Military Aerospace	Military Non-Aerospace
2005	$46,027	$68,919	$60,517	$5,528	$2,873	$22,892	$20,055	$2,014	$823
2006	61,372	86,419	75,123	8,062	3,233	25,047	21,854	2,077	1,116
2007	68,537	99,464	87,991	7,631	3,843	30,927	26,582	2,437	1,908
2008	72,111	103,577	86,557	13,421	3,600	31,466	26,748	2,515	2,203
2009	54,502	90,246	75,034	11,556	3,657	35,745	30,453	2,563	2,730
2010	50,500	87,726	72,032	11,471	4,223	37,226	31,458	2,966	2,803
2011	54,392	95,748	80,474	10,967	4,306	41,356	35,778	3,253	2,324
2012	66,387	112,970	95,101	13,431	4,438	46,582	40,335	4,017	2,230
2013	71,430	124,385	106,081	13,963	4,341	52,954	47,170	3,446	2,338
2014	76,132	135,568	114,233	16,116	5,218	59,435	53,535	3,899	2,002
2015	81,613	142,824	121,768	15,422	5,633	61,211	55,482	3,805	1,924
2016	90,335	145,985	123,660	16,199	6,126	55,650	49,756	3,886	2,008
2017	85,901	142,825	122,790	13,865	6,170	56,924	50,725	4,464	1,736

Source: Aerospace Industries Association (AIA), based on data from the U.S. Department of Commerce, 2018.
Note(s): Totals may not equal sum of terms due to rounding.
Commodity classifications based on the U.S. Harmonized Tariff Schedule.
Contact: For more information, contact the Aerospace Research Center at research@aia-aerospace.org.

Figure 3. U.S. Exports, Imports and Balance of Trade. The 2005 – 2017 export and import comparison highlights the consistent trade imbalance for each of these export categories, which totaled nearly $86 billion in 2017.[154]

APPENDIX D
U.S. EXPORTS OF AEROSPACE PRODUCTS

U.S. EXPORTS OF CIVIL AND MILITARY AEROSPACE PRODUCTS

Calendar Years 2012-2017

(Millions of Dollars)

	2012	2013	2014	2015	2016	2017
TOTAL AEROSPACE EXPORTS	$108,532	$120,044	$130,293	$137,222	$140,025	$136,655
TOTAL CIVIL AEROSPACE	$95,101	$106,081	$114,233	$121,802	$123,820	$122,790
Complete Aircraft	(D)	(D)	(D)	(D)	(D)	(D)
Transports						
General Aviation						
Helicopters						
Other Fixed Wing						
Used and Rebuilt Aircraft						
Aircraft Engines						
Piston						
Turbine						
Aircraft and Engine Parts						
Missiles, Rockets, and Parts						
Spacecraft, Satellites, and Parts						
TOTAL MILITARY AEROSPACE	$13,431	$13,963	$16,061	$15,420	$16,205	$13,865
Complete Aircraft	$3,446	$2,802	$5,052	$3,682	$4,541	$2,464
Fighters and Bombers	737	0	0	0	469	648
Transports	1,410	1,450	2,965	1,520	1,411	779
Helicopters	690	948	1,618	1,886	2,266	783
Other Fixed Wing	161	110	177	242	228	201
Used and Rebuilt Aircraft	447	294	292	34	167	52
Aircraft Engines	437	634	952	740	582	667
Piston	66	157	188	148	119	218
Turbine	371	476	764	592	463	449
Aircraft and Engine Parts	7,356	7,382	7,264	7,712	7,914	7,799
Missiles, Rockets, and Parts	1,739	2,580	2,273	2,725	2,695	2,441
Spacecraft, Satellites, and Parts[a]	453	565	519	561	472	495

Source: Aerospace Industries Association (AIA), based on data from the U.S. Department of Commerce, 2018.

Note(s): Totals may not equal sum of terms due to rounding.

Commodity classifications based on the U.S. Harmonized Tariff Schedule.

D. Civil aerospace export data suppressed by U.S. Census Bureau beginning first quarter 2009.

a. Includes training devices, parachutes, and parts.

Contact: For more information, contact the Aerospace Research Center at research@aia-aerospace.org.

Figure 4. U.S. Exports of Aerospace Products. In 2017 within the Military Aerospace category, the U.S. exported $2.4 billion in Complete Aircraft, $667 million in Aircraft Engines, and close to $7.8 billion in Aircraft and Engine Parts which underscores the positive economic impact to the U.S. industrial base.[155]

APPENDIX E
BOEING DEFENSE SYSTEMS AIRCRAFT

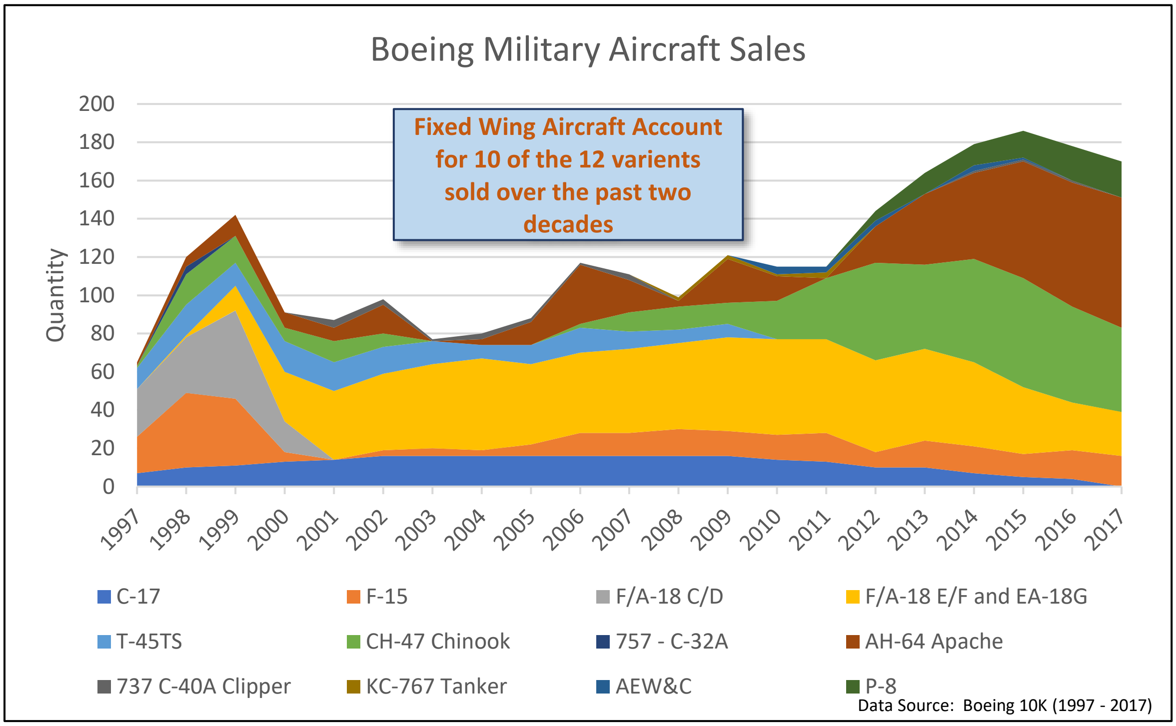

Figure 5. Boeing Military Aircraft Sales (1997 – 2017)[156]

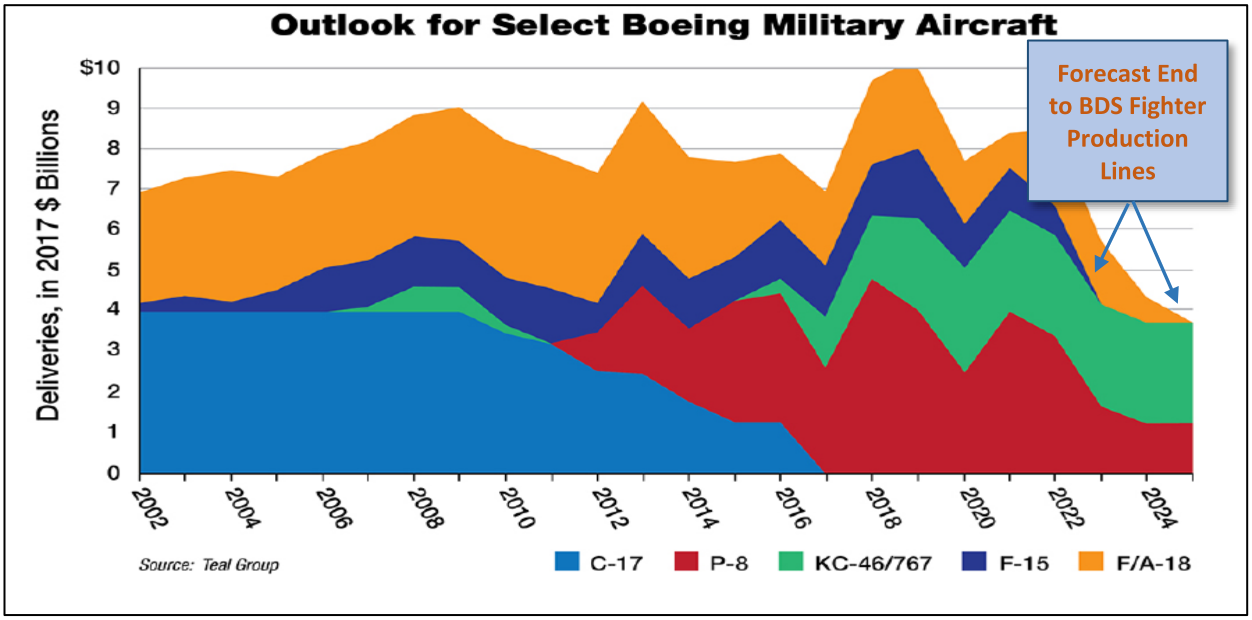

Figure 6. Historical and Forecast Boeing Military Aircraft Fixed Wing Revenue[157]

APPENDIX F
MAJOR ARMS EXPORTERS

	Exporter	Share of arms exports (%) 2013–17	Share of arms exports (%) 2008–12	Per cent change from 2008–12 to 2013–17[a]	Main clients (share of exporter's total exports, %), 2013–17: 1st	2nd	3rd
1	United States	*34*	*30*	*25*	Saudi Arabia (*18*)	UAE (*7.4*)	Australia (*6.7*)
2	Russia	*22*	*26*	*–7.1*	India (*35*)	China (*12*)	Viet Nam (*10*)
3	France	*6.7*	*5.8*	*27*	Egypt (*25*)	China (*8.6*)	India (*8.5*)
4	Germany	*5.8*	*7.4*	*–14*	South Korea (*14*)	Greece (*11*)	Israel (*8.7*)
5	China	*5.7*	*4.6*	*38*	Pakistan (*35*)	Bangladesh (*19*)	Algeria (*10*)

Figure 7. Five Largest Exporters of Major Arms. The five largest arms exporters over the last 10 years (2008 – 2017) were the U.S., Russia, France, Germany, and China.[158]

APPENDIX G
EXPORT ADMINISTRATION REGULATIONS (EAR)
FAVORABLE TREATMENT COUNTRIES

LE ENC Favorable Treatment Countries — Supplement No. 3 to Part 740– page 1

SUPPLEMENT NO. 3 TO PART 740 - LICENSE EXCEPTION ENC FAVORABLE TREATMENT COUNTRIES

Australia	Germany	New Zealand
Austria	Greece	Norway
Belgium	Hungary	Poland
Bulgaria	Iceland	Portugal
Canada	Ireland	Romania
Croatia	Italy	Slovakia
Cyprus	Japan	Slovenia
Czech Republic	Latvia	Spain
Denmark	Lithuania	Sweden
Estonia	Luxembourg	Switzerland
Finland	Malta	Turkey
France	Netherlands	United Kingdom

Figure 8. EAR Favorable Treatment Countries. The EAR specifies 36 countries that are deemed by the U.S. as Favorable Treatment Countries. [159] Australia, Canada, New Zealand, and the United Kingdom represent trusted friends and allies of the Five Eyes intelligence alliance.[160]

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