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INDUSTRY STUDY

FINAL REPORT
AIRCRAFT INDUSTRY

The Dwight D. Eisenhower School for National Security and Resource Strategy

National Defense University

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AIRCRAFT INDUSTRY STUDY 2014

ABSTRACT: The 2014 Eisenhower School Aircraft Industry team analyzed firm strategies in the current budget environment of declining defense spending and the implications for the U.S. government. Interviews were conducted with key domestic defense aircraft firms and suppliers with emphasis on firm strategies in the next 3-5 years. The research team identified key trends shaping both the domestic and international business environments, focusing on the effects of government budget and priority uncertainty, infrequent "winner take all" programs, firm consolidation, competition, and program affordability. Maintenance, repair, and overhaul revenue, and rising complexity in foreign sale offset requirements were analyzed in the context of the increasing importance of foreign markets to domestic firms. Further, this research analyzes the Joint Strike Fighter as an acquisition and industrial model and its potential impact on industry structure. Advantages and disadvantages of the JSF model are presented, with implications for future procurement programs such as the Army's Future Vertical Lift. General firm strategies are described and fundamental government needs from industry are identified. Current dynamics and likely firm strategies are analyzed for the following market segments: fighters, unmanned aircraft systems, mobility aircraft, large commercial aircraft, special mission and commercial derivatives, and rotary wing. Finally, considerations for the U.S. government in light of current market dynamics and firm strategies are presented.

Seminar Members:

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Mr. Tonico Beope, Dept of the Air Force	Col Shaun Hick, U.S. Air Force
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INDUSTRY FIRM VISITS

Fixed-wing Aircraft Prime Integrators and Manufacturers	
Boeing, St. Louis, MO	F/A-18E/F, EA-18G, F-15E variants
Lockheed Martin, Fort Worth, TX	F-35, F-16
Lockheed Martin, Marietta, GA	C-130J, C-5
Boeing, Everett, WA	747, 767, 777, 787, KC-46
Boeing, Renton, WA	737, P-8
General Atomics, San Diego, CA	MQ-1, MQ-9
Lockheed Martin Skunk Works, Palmdale, CA	U-2, Special Missions
Northrop Grumman, Palmdale, CA	RQ-4
Rotary-wing Aircraft Prime Integrators and Manufacturers	
Sikorsky Aircraft Corporation, Stratford, CT	H-60 variants
Boeing Rotorcraft Systems, Ridley Park, PA	V-22, CH-47
Bell Helicopter, Amarillo, TX	V-22, UH-1Y, AH-1Z, Model 525
Engine Manufacturers	
Pratt & Whitney, CT	Commercial and military engines
Turbomeca USA	Commercial and military engines

GUEST LECTURES

Richard Aboulafia	Vice President, Analysis, Teal Group Corporation
Vangala Ram	Director, Office of Regional Security and Arms Transfers, Bureau of Political Military Affairs, U.S. Department of State
W. Alexander Vacca	Corporate Director, Business Analysis, Northrop Grumman Corporation
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Michael Vaccaro	Director, Office of Strategic Industries & Economic Security, Bureau of Industry and Security, U.S. Department of Commerce
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1. INTRODUCTION

Thesis

A combination of long-cycle trends in the defense aircraft industry and near-term decline in U.S. defense spending are resulting in firm strategies and an industry structure that present new and increased risks to national security, yet provide opportunities to shape the strategic, technological, and industrial landscape of the future. Because government behavior largely drives the industry, the U.S. government must: 1) characterize the industrial base required to meet its long-term aircraft needs, 2) identify those factors that most significantly affect the industry's ability to meet national security needs, and 3) establish policy and acquisition practices that address these factors in shaping the industry toward the desired state.

Motivation

The vitality of the domestic aircraft industry figures prominently in any assessment of options for ensuring long term U.S. national security. Structurally, the U.S. relies extensively on private industry to design, develop, produce, and sustain the aircraft weapon systems needed for its armed forces. This historically domestic industry base is increasingly global with competition among few domestic suppliers for fewer programs with increased technological complexity. In light of the near-term downturn in defense spending, defense aircraft company responses naturally focused on strategies to continue growth in ways that didn't always include technical innovation or competitive positioning in line with U.S. government interests to maintain a healthy market capable of meeting defense needs. Indeed, recent studies have examined the ability of the industry to meet future defense aircraft needs, and questions have arisen over the projected adequacy of the base to supply needed innovation at a reasonable cost through competition in combat aircraft markets.[1]

Research Methodology and Limitations

Research was conducted from February-May 2014 and included analysis of open-source data, reports, and studies. Research team visits to firms listed on page ii were conducted in April-May, 2014. This report is unclassified and all firm interviews were held at the unclassified level. The impact of "black" programs on the defense aircraft industry was not considered in this study.

2. DEFENSE AIRCRAFT INDUSTRY IN STRATEGIC CONTEXT

National Interests and the Role of Defense Aircraft

The role of aircraft in meeting the national security needs of the U.S. is pervasive. As stated in the most recent National Security Strategy (2010), the national security interests of the U.S. are: ensuring security for the country, allies, and partners; maintaining a strong economy; respect for universal values; and maintaining peaceful, secure international order through cooperation.[2] As described in the 2014 Quadrennial Defense Review (QDR), the military supports these interests through three strategic pillars: protect the homeland, build security globally, and project power and win decisively.[3]

Through all three pillars, and in all four national interests, the defense aircraft industry plays a leading role. As reflected in the President's FY15 budget proposal, aircraft spending for the armed services led all investment categories except mission support. Aircraft accounted for $40.0B in procurement and RDT&E spending (26% of total DoD investment spending), versus the next biggest category of shipbuilding & maritime systems with $22.0B budgeted (14.3% of investment spending).[4] In the broader economy, the domestic aerospace industry accounted for $220B in sales in 2013, with $56B attributed to the sale of military aircraft (versus $67B in sales of commercial aircraft, with the remainder in space, missiles, and related products & services).[5] The U.S. aerospace industry is consistently the leading net exporter of manufactured goods ($111.9B in 2013 exports vs $38.5B in imports), with about 88 percent of the exports arising from the civil sector.[6] However, U.S. aerospace firms dominate global arms exports: 7 of the top 10 global arms sellers are U.S. aerospace firms, and all of the top 10 are aerospace companies that together represent 50% of the Top 100 global arms sales total of $395B (as of 2012).[7] The top two defense firms in the world (in defense sales) are U.S. aircraft manufacturers Lockheed Martin and Boeing. As a result, the U.S. defense aircraft industry provides the country a strategic advantage in building partnerships and ensuring peaceful international order as the U.S. leverages exports and Foreign Military Sale (FMS) programs to build the capabilities of allies and partners with equipment that is interoperable, supportable, and technologically advanced.

Recent Budget Environment

Nonetheless, the defense aircraft industry has dealt with significant recent budget reductions in all services, with only a handful of programs remaining untouched by the reductions. For the Department of the Navy, aircraft procurement funding has declined 22% since FY12, and the Air Force experienced 25% cuts in aircraft procurement funding from FY12-14.[8] Likewise, the Army has seen aircraft procurement funding decline over 20% for the period FY12-15.[9] Similarly, DoD RDT&E funding has seen a decline of 20% from FY10 to an FY15 topline value of $63.5B, with impacts to the aircraft industry's ability to rely on DoD for funding to develop next generation aircraft and subsystems.[10]

Looking forward, the Air Force and Navy budgets for FY15-19 project increases in aircraft procurement and RDT&E funding from their FY15 base. In the case of the Air Force, the increase is dramatic, buoyed by a $4B increase in procurement (from a $7B FY15 base) from FY15 to FY16 to cover anticipated costs in F-35, KC-46, and numerous variants of the C-130.[11] Likewise, the Department of the Navy projects future aircraft procurement budget requests around $11B per year through the FYDP, largely for F-35 and P-8, but also including MV-22, E-2D, and rotary wing aircraft.[12] Notably, F-18 funding ends in 2014 with no new funds requested in 2015. For the Army, further funding reductions of approximately 20% are projected through FY19, primarily impacting rotary wing aircraft.[13] As a result, overall fixed-wing aviation investment funding (RDT&E plus procurement), is projected to increase 6.85% on average from FY15 to FY19, while Uninhabited Aerial System (UAS) and rotary wing funding is projected to decline 6% to 7% annually over the same time period.[14]

U.S. Strategic Choices

Technology Supremacy. Historically, the U.S. armed services demand ever increasing performance in their weapon systems, seeking to ensure a technological edge over other nations. Technological supremacy has become a key element in the American approach to war, but as operations in Afghanistan and Iraq wind down, focus is shifting to the competitive demands of the Asia-Pacific where achieving operational meaningful quantities of assets may require trade-offs between cost and capability, especially in light of economic pressures that limit available military budgets.

Quality vs Quantity. Projecting power over the vast distances in the theater, and planning for operational success in contested airspace against the limited timeframes anticipated, will require hard choices in risk acceptance as quantity versus quality trades are considered. The resulting uncertainty will likely drive both government and industry to be conservative in their approaches, which may limit opportunities for innovation in the absence of programs that share risk.

Protracted Operations. The defense aircraft industry plays a leading role in providing DoD the resources needed to implement its strategy for securing U.S. national interests. Central to this mission is the current industrial base's capacity to support protracted military operations in a contested environment. Further analysis and issues for government consideration are presented in section 8 of this report.

3. STRUCTURE & INTERACTIONS OF THE DEFENSE AIRCRAFT INDUSTRY

From Arsenals to Private Firms

Government-business interaction in the defense aircraft industry has evolved since the invention of the aircraft to a state where the U.S. relies almost completely on private industry to meet its defense aircraft needs for national security. Recognizing the significant contribution a domestic aircraft industry makes to the nation's economic base, U.S. policy emphasizes free market competition in producing world-leading innovation at an affordable price. But this state of affairs evolved over time, as military officials in the interwar years between World War I and II turned to commercial aircraft firms to rapidly develop and produce aircraft with the latest technologies.

As developed by Thomas McNaugher, the traditional arsenal approach of separating R&D from production proved inadequate to keeping up with the rapid technological advances in military aircraft during the interwar period: the arsenal system simply couldn't respond to change fast enough to produce meaningful quantities before new designs made existing production obsolete.[15] World War II proved the value of the new approach, and the necessity of continuing rapid aircraft innovation during the Cold War continued the emphasis on private industry as the source for innovation and production, but with an increasingly complex government oversight role developed as a way to satisfy an ever increasing range of government stakeholder requirements (e.g. from Congress and the Office of the Secretary of Defense). McNaugher characterized this as reflective of the overall American approach to its military, industry, and political system that evolved as a result of the unprecedented peacetime stresses of the Cold War.[16]

Post-Cold War Changes

By the end of the Cold War, the U.S. possessed a domestic aircraft industry that was the world leader in both military and civil aircraft. In military aircraft, the late Cold War development of stealth technology designed to defeat Soviet air defense systems was part of a revolutionary change in aerial warfare that gave the U.S. an asymmetrical advantage that continues to this day. However, with the end of the Cold War and a subsequent decline in defense spending through the 1990s, a dramatic consolidation of the aerospace industry resulted in just two top-tier prime contractors capable of designing and producing new combat, fixed-wing aircraft: Lockheed Martin and Boeing.[17] Northrop Grumman continues to possess in-house capabilities for fixed-wing, military aircraft design and production, but the competitiveness of its abilities beyond Global Hawk is now debatable.[18] In contrast, prior to the 1990s consolidation, eight historical domestic combat aircraft producers supported a wide variety of Cold War designs and production lines. The remaining two firms have become conglomerates with businesses in wide ranging areas including military aircraft, space systems, missiles, information technology, shipbuilding (for Lockheed Martin), and commercial aircraft (for Boeing).

In the rotary wing market, three domestic suppliers vie for new production: Boeing, Sikorsky (as part of United Technologies), and Bell (as part of Textron). Similarly, leading domestic suppliers of medium and high-altitude UASs consist of General Atomics and Northrop-Grumman. For mobility aircraft, Boeing and Lockheed Martin are the only viable domestic primes in the airlift market, while Boeing remains the only domestic producer of strategic tankers.

Downturns Contrasted: Today vs. 1990s

Today's defense downturn differs from that of the 1990s in three key ways: 1) the options for consolidation are fewer, 2) industry structure has changed where many critical niche capabilities now reside in lower tiers as prime contractors become integrators, and 3) the supply chain is globalized. How will industry respond this time? Dr. Frank Kendall, Deputy Under Secretary of Defense for Acquisition, Technology and Logistics, stated that further consolidation at the top tier would not be in the best interest of DoD. He also stressed that at lower tiers the Department would be watching for anticompetitive situations or the loss of critical capability.

However, as budgets decline, firms may view consolidation as an enticing option and even necessary. If this does not occur at the top tier, it is at least likely at the lower tiers. Elana Broitman, Acting Deputy Assistant Secretary of Defense for Manufacturing and Industrial Base Policy, recently expressed concern about lower tier consolidation and stated that the Department will potentially use its own funds or allow some mergers and acquisitions to ensure that niche lower tier capabilities are maintained.

Another dynamic is the extent of globalization that has occurred since the 1990s. Previously, government actions fostering U.S. defense consolidation were intended to help maintain adequate *domestic* competition. However, in the current globalized environment, defense leadership will have to consider international competition in developing industrial base policy. This could result in further domestic firm consolidation throughout the supply chain because foreign providers are considered reliable. DoD clearly recognizes that market forces may drive further industry consolidation or vertical integration, and the department may acquiesce in some instances. In order to balance all the forces at play, DoD may take a "hands-on" approach to ensure that industrial capabilities will be maintained while keeping the necessary level of competition.

Key Structural Features of the Aircraft Industry Today

Distinct yet interconnected market types. As the monopsony buyer in the largest defense market in the world, the U.S. government holds significant power in its ability to shape the aircraft industry. Aircraft firms compete in one or a combination of three markets: commercial, military, and foreign. Where a firm decides to compete depends on the product/platform and level of diversification the firm deems required to meet shareholder expectations. Most major U.S. aircraft firms have divisions or subsidiaries that serve commercial and military sectors. This

facilitates development of business strategies to leverage the strengths and weaknesses of each sector while weighing the current market/business environment to apply resources at the appropriate time to achieve business objectives. Some firms, such as Lockheed Martin and General Atomics, are mostly dependent on defense contracts, and therefore seek diversification opportunities primarily in adjacent defense markets.

In the **commercial** sector, Boeing is the only U.S. manufacturer of wide-body transport aircraft with its competition almost exclusively from Airbus. The rest of the U.S. civil market relevant to defense aircraft consists primarily of business jet and civil rotorcraft manufacturers. However, competition in some these markets is high, such as small to medium size commercial helicopters. Of note, the U.S. does not possess a domestic manufacturer of so-called regional jets.

Competition in the domestic **military** market is predominately limited to a few U.S. based firms in each sector. For example, a single domestic firm competes for strategic tankers and there are essentially three domestic suppliers that compete for military rotary wing programs. Infrequent programs and high complexity of some platforms present barriers to entry for new entrants, and opportunities to leverage civil aircraft designs primarily exist in tankers and special purpose ISR aircraft.

Foreign markets consists of both commercial and military sectors. For many firms, foreign markets may be as important as domestic markets. In some sectors competition is high both from other domestic firms and a growing list of foreign manufacturers that often enjoy state backing. U.S. defense aircraft firms have traditionally looked to foreign markets during periods of domestic spending decline, but this dynamic is shifting due to an increase in defense spending in many regions and "rise of the rest" global economic trends. U.S. defense firms are now establishing more aggressive footprints in foreign markets, although barriers to entry are often high. Relevant trends include U.S. government controls on technology, foreign preference for indigenous "national champion" suppliers, demands for offsets, and government/industrial partnering.

Rise of Diversified Conglomerates. Aircraft-producing firms in the U.S. are no longer "aircraft companies" in the historic sense. This change, with strategic implications, is due to the interaction of two factors. First, restructuring and consolidation of the defense industry in recent decades has fostered the creation of large conglomerates with diversified business portfolios, of which aircraft design and production may be one portion. Aircraft companies in previous eras were run by company founders who were primarily engineers and strongly loyal to the defense or aviation mission. Today's conglomerates are run by financial officers with a focus towards investor and shareholder interests. Second, defense conglomerates rely heavily on U.S. government contracts for revenue and are therefore very sensitive to changes in U.S. defense budgets. For example, Lockheed Martin derived more than 80% of its 2013 revenue from the

U.S. government, with only 1% from commercial sales and 17% from international sales (largely defense related).[19]

Together, these two industry characteristics combine to increase the likelihood that portfolio management and investor-driven growth goals may induce firms to exit specific aircraft markets during periods of declining/flattened defense spending, and may never re-enter. The U.S. government should therefore consider whether open market policies used in the past will be sufficient to meet DoD needs in the future.

Changing roles for primes and suppliers. The tasks of integrating complex aircraft, building global supply and logistics networks, and navigating a complex acquisition system consume nearly all resources of the prime manufacturer, pushing design and manufacture of major subcomponents and systems to an increasingly global array of 2nd and 3rd tier suppliers (see Figure 1). Today, modern aircraft primes typically rely on lower tier suppliers to produce around 70% of new aircraft components.

Today's second tier suppliers therefore are often assuming a role similar to that of prime firms of the past, building sub-assemblies that exceed the size, complexity, and cost of whole aircraft built by prime firms in previous eras. For example, Northrop builds the F-35 center fuselage for Lockheed Martin and the F-18 center/aft fuselage and tails for Boeing. This feature of the vertically fractured supply chain has implications for innovation that will be developed further a later section.

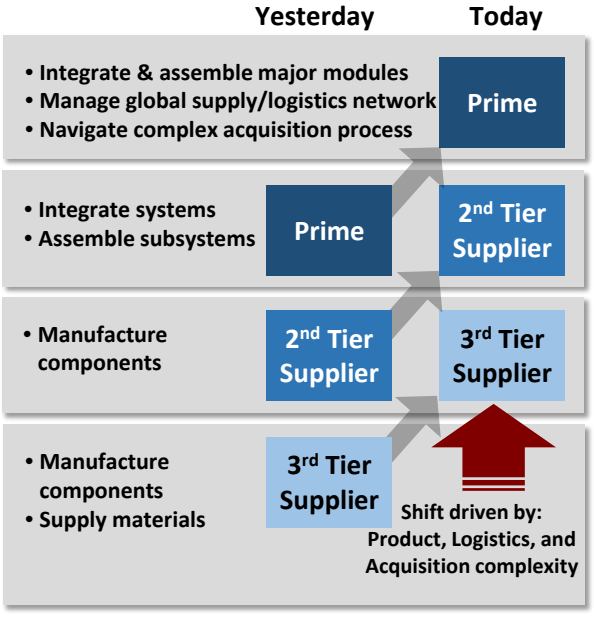


Figure 1. Shift in supplier roles and competencies

These structural features and interactions between government and industry inform subsequent analysis of key trends in the domestic defense aircraft industry.

4. KEY INDUSTRY TRENDS

Four industry trends were identified as having long term, wide ranging, and interrelated consequences for the defense aircraft industry. Two trends are summarized briefly (developed further in other sections of this report), and others are here analyzed in detail. This section ends with consideration of the JSF acquisition model as culmination of these major trends and dynamics.

Trend #1: Uncertainty in magnitude and priorities in U.S. Defense Spending

Government drives industry behavior. The defense aircraft industry is fundamentally driven by government policy and acquisition behavior. As the monopsony buyer in the largest defense market in the world, and export control authority for foreign markets, the government holds significant power in shaping the industry, in spite of policy that seeks to maintain free market conditions. In particular, the way that government structures each competition, and the requirements it sets for performance, cost, and schedule, largely determine which business models will succeed over the long run, ultimately altering the structure of the industry to match.

Uncertainty induces firms to adopt conservative strategies with near-term focus. Firm strategies are significantly affected by the magnitude, predictability, and priorities of defense budgets. Although budget magnitude often gets more publicity, uncertainty is the larger enemy of industry's ability to meet DoD needs. In an uncertain budget environment, long-term R&D and capital investment commitments are too risky, and unpredictable production quantities threaten revenue models.

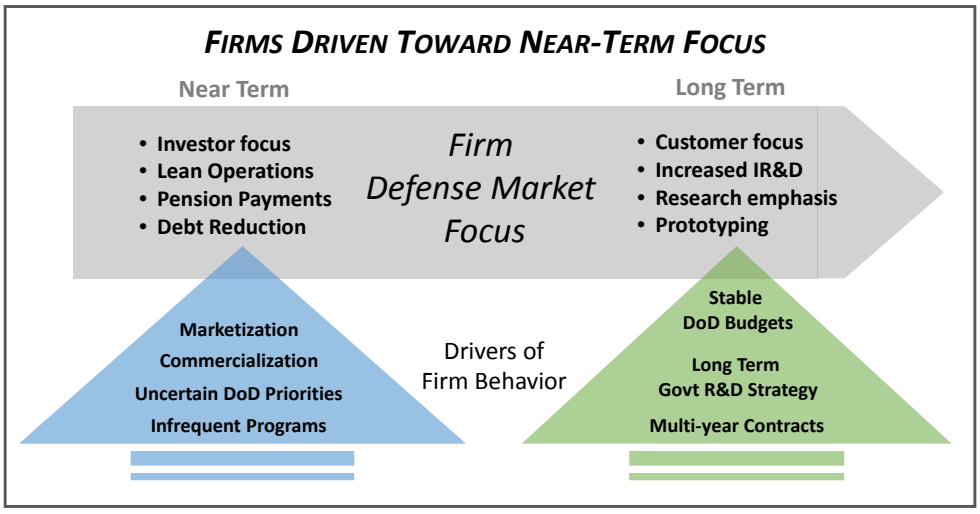


Figure 2. Firm behavior in an uncertain business environment

As depicted in Figure 2, firms are also driven toward a near-term and conservative focus by marketization (response to investor values), commercialization (growth of commercial markets relative to defense) and infrequency of major defense aircraft programs. In contrast,

predictable defense technology/capability priorities enable firms to develop business strategies that complement government interests.

Budget scenarios. As projected in the President's FY15 budget submission, the recent downturn in defense spending since 2010 appears to be abating, with flat to slightly rising budgets projected from FY15-19. This may be a best case scenario, as the most recent budget submission includes projections that exceed current Sequestration values by $115B for FY16-19.[20] If so, DoD will likely have to work within existing top lines of around $600B or less as it seeks to meet its QDR goals and rebalance to the Asia-Pacific region, maintain strong commitment to security and stability in Europe and the Middle East, counter violent extremist threats, emphasize technology advancements, and invigorate partnerships with key allies.[21]

However, the past few budget cycles have seen DoD consistently overestimate Congressional support for future budgets. As a result, the domestic defense aircraft industry still views future budgets as possibly declining, rather than rising or staying stable, and the uncertainty is driving their behavior. If past budget downturns are a guide, the current downturn may still be a few years from its bottom, with additional declines of 15-25% in procurement and RDT&E accounts remaining before the trough is reached around 2020.[22]

The firms visited were keenly aware of the range of budget scenarios that may play out over the next few years. One experienced industry analyst captured the range of possible future scenarios in five categories. Three of the potential scenarios characterize the extent of the budget uncertainty:

Budgets begin to increase: Future budgets will actually begin to rise as the economy recovers and strategic imperatives require increased defense spending. The implication is no major restructuring of the industry will occur.

Spending stays flat, and industry and government muddle through: this is basically the government's current budget, as projected, with major upheavals in rebalancing, resulting in firms muddling through the existing, projected budget environment.

Inflection and short term decline: Supposes government budgets are actually at an inflection point and will continue to decline, perhaps dramatically, for the next few years as underlying economic weakness and budget demands by non-discretionary accounts keep defense budgets weak. Any recovery in spending would be too late to forestall upheavals in industry structure, as firms may have to contemplate dramatic changes in market participation or risk collapse.

Long term decline. This is the first of two exogenous scenarios and is unlikely. If realized, it may require aggressive government market intervention to preserve adequate industrial capacity in military aviation. Similar to the approach taken in many other countries, the government would bail out selected firms and take ownership of a "golden share," in effect creating a national champion for certain markets.

New Revolution in Military Affairs. In this second exogenous scenario, the emergence of a new Revolution in Military Affairs (RMA), or perhaps a revolution in management, would result in a natural restructuring of industry around new principles of warfare or government-business relations.

In predictable budget environments, firms stand a better chance of "muddling through" successfully, as long as any declines in budget aren't too severe. But in unpredictable budget environments, firms struggle to identify program "winners" and "losers," and thus take a conservative approach to strategy. In particular, during unpredictable but declining budgets, firms may seek to protect themselves from budget instability by exiting defense markets. As conglomerates, the largest aircraft manufacturers are run by CEOs with financial expertise, and in recent years, the demands of meeting shareholder expectations to find growth wherever it occurs have been seen to trump commitment to staying in defense lines of business that are no longer profitable.

Impact of uncertainty on Research and Development: Firms' conservative approach to strategy in unpredictable budget environments has other effects, particularly on R&D spending. Consistent, clear government communication on requirements and competitive approach enables industry to prioritize internal R&D spending for maximum market impact. In the absence of predictability, industry errs on the side of caution, relying on government R&D programs to provide funding for required technological innovation. With declining budgets, this behavior lies in tension with government desires to see more company R&D dollars spent to advance technology.

The end result is that innovation has become very incremental, with conservative approaches by industry that may not match well with the desired strategic shift to the Asia Pacific. Much depends on government requirements for that theater: will they continue to emphasize the role of technology to defeat anti-access threats and opposing force size, or will operational concepts that emphasize quantity and affordability emerge that would change the nature of innovation required by industry? Meanwhile, the rest of the world continues to develop and produce defense aircraft that are competitive in a wide range of environments, putting pressure on the legacy product lines of the U.S. domestic industry. This further pressures revenues that could be used to generate R&D dollars, resulting in a decelerating domestic innovation process at the same time much of the world's technology development is accelerating and catching up.

Trend #2: Increasing supply chain globalization and foreign competition in historically domestic markets

The increasingly global nature of the aircraft supply chain mirrors developments in other manufacturing industries. Rising competition from foreign suppliers, lower labor and material costs, the advancement of technology in developing economies, and the use of offset requirements by foreign governments as a way to accelerate development of indigenous aircraft

industries, are all drivers of a more globalized aircraft industrial base. Even high tech defense programs such as the F-35 have an element of globalization as many of the foreign buyers have industrial cooperation agreements. As a result, competition is shifting from what use to be primarily a domestic industrial base to a global base in a wide array of markets such as MRO, manufacturing of aircraft subsystems and components, rotorcraft, non-stealth combat aircraft, training aircraft, and the upgrade/modernization market.

Regional threat impacts. A second factor contributing to supply chain globalization is the response to regional threats. Regional threats are driving states to more quickly acquire aircraft products and develop indigenous capabilities to sustain them. As an example, China's challenge to the aviation market and rise as a regional power in the Asia-Pacific has caused other regional states to procure advanced aircraft at a faster rate in order to counter the potential threat. The same dynamic could also be said for countries in MENA in response to Iran. Many of these emerging economies view the development of an indigenous aerospace industry as important to their national interest and economic growth.

Industrial maturity tiers. To aid in understanding global production capabilities and the dynamics that have emerged, Kevin Krause categorizes defense production capabilities in a three tier structure.[23] Tier I is defined by suppliers that are at the "highest levels of technological sophistication across the entire range of defense production and who are not economically reliant on foreign sales."[24] Some experts argue that the United States is currently the only Tier I supplier. Tier II suppliers "have some research and development capabilities and exhibit areas of technological sophistication"[25] often referred to as niche capabilities. Niche capabilities can be on par with Tier I producers. Tier II countries are heavily reliant on exports to sustain their industrial base and are the largest group of exporting countries. Most Tier II countries seek to develop niche capabilities and enter the global supply chain. Tier III suppliers "show less technological sophistication and often do not progress beyond slightly modifying products made under license."[26]

The starting point for a buyer to introduce industrial capability within its domestic economy "is to begin initially making weapons systems under license (third tier production) and then progress to upgrading it, with the aim of learning to be able to design new versions."[27] When one considers the economic goals of emerging states such as in the Indo-Asia-Pacific and the Gulf/MENA regions, the result is that countries procure products and demand industrial capabilities to accompany the product at the tier II and III levels with the goal of being able to provide some level of sustainment of their own platforms while competing globally for the same effort in other markets. This factor inherently increases the element of globalization within the industry.

Foreign competition in U.S. markets. Another facet of globalization is the increasing access of foreign firms to U.S. markets. Foreign companies are partnering with existing U.S. firms as they seek to compete in the U.S. marketplace. For example, Airbus (then EADS)

partnered with Northrop Grumman as the prime on the KC-X competition. Alenia partnered with L-3, as the prime, for the C-27J competition. For the upcoming T-X competition, all the competitors for the next U.S. jet trainer have partnered with a foreign aircraft designer and manufacturer to offer derivative systems of foreign base designs.[28] Notably, the four teams that have announced an intent to compete each include a U.S. prime contractor in partnership with a foreign aircraft manufacturer: Lockheed Martin with KAI on the T-50, BAE systems with Northrop Grumman and others on the Hawk, General Dynamics with Alenia Aermacchi on the T-100, and Boeing with Saab on a new, "clean-sheet" design.[29] These examples illustrate the growing access to U.S. markets by foreign completion.

Risks of globalization. Globalization of the supply chain presents two significant risks. The first is technology diffusion. The proliferation of platforms and systems combined with the increased technology transfer and industrial participation demands of emerging nations leads to a level of uncertainty in the technological environment. The increased level of uncertainty increases the likelihood of being surprised by nation that is able to absorb and improve on a transferred technology. The second risk is with the challenge of managing the global supply chain so critical sources of supply and key niche capabilities that may be only available through a few sources are available when required. Each of these risks will be addressed again in later sections.

Trend #3: Firms increasingly rely on MRO revenue streams

Revenue from Maintenance, Repair, and Overhaul (MRO) is increasingly important to aircraft manufacturers and is a core strategy element for many firms.[30] As R&D and production budgets shrank in the 1990s, followed by significant increases in Operations and Maintenance (O&M) budgets during the 2000s as a result of American operations in Iraq and Afghanistan, the MRO business became a consistent growth area in every firm's portfolio.

As firms consider their business cases for new programs, they increasingly trade revenue in development and production for income during later phases of a system's life cycle. In spite of the risks of program cancellation or open completion for sustainment contracts, this strategy is understandable in an environment of infrequent winner-take-all competitions. This topic is analyzed in more detail in section 8.

Trend #4: Government requirements drive reduced competition and capacity through large, complex, infrequent aircraft programs

The defense aircraft industry has responded to U.S. government requirements for technologically dominant systems that provide unparalleled capabilities in air warfare. But U.S. technological dominance has come at a price. User demands for revolutionary technologies drive increasing system complexity, which cascades into industry-shaping downstream effects. Challenges with maturing leading-edge technology and the complexity involved with integrating advanced systems has frequently lead to unanticipated technical challenges during development

and other second-order effects, requiring modification and/or addition of subsystems. For example, the F-22 program planned for only three software iterations during initial developmental flight test, yet required nearly 100 software releases.

Testing advanced systems is also more costly and time consuming than often planned for due to the need to test in operationally relevant simulated threat environments that have much greater scale than historical operational scenarios. Because complexity drives high cost and long development timelines, the frequency of new programs decreases. This dynamic raises user expectations for higher performance from subsequent designs. This vicious cycle continues, as both the systems and the organizations that procure them rise in cost and complexity (see Figure 3).

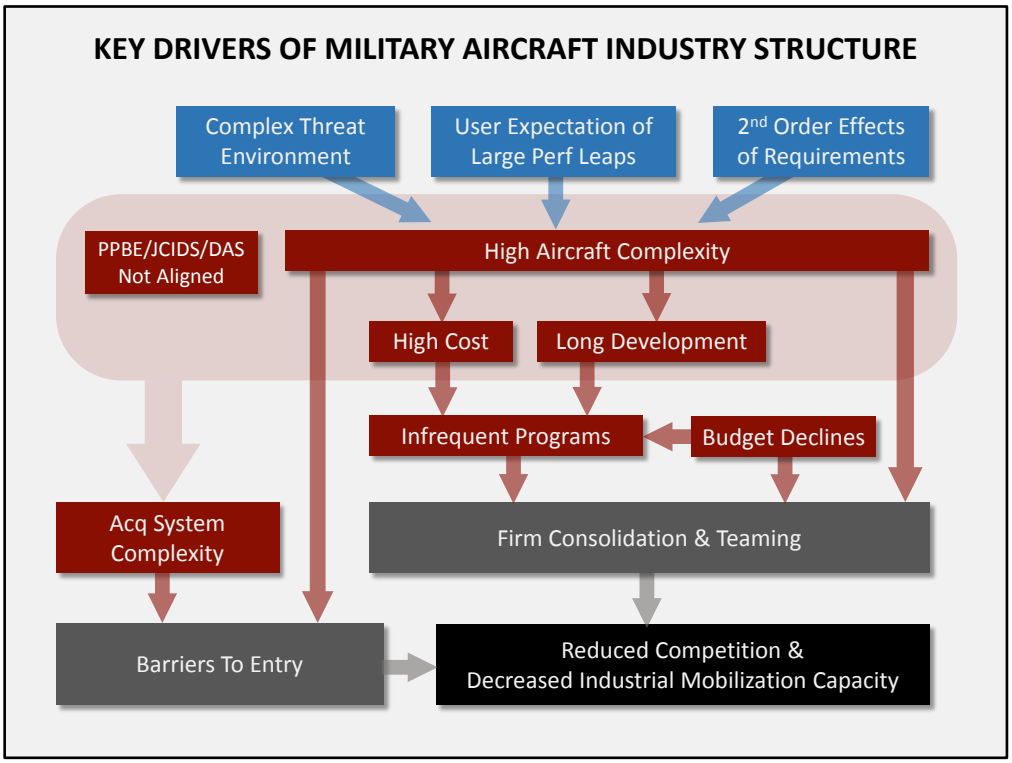


Figure 3. Key drivers of military aircraft industry structure

Increasing aircraft complexity. Primary technical drivers of aircraft complexity are stealth, high reliance on software, low-weight designs required to meet performance demands, and speed/maneuverability. For example, the F-16 had 15 subsystems and fewer than half of its functions were controlled by software. The F-35 has 130 subsystems and is reliant on software for 90% of its functions.[31] Associated higher computing power requires complicated cooling

systems, and functional interactions via thousands of interfaces often result in negative emergent behavior[1] during development.

According to industry interviews, broader government regulations have also increased complexity. Growing reliance on specialty metals and materials is exacerbated by supply restrictions established in the Berry Amendment and the Buy American Act.[32] Environmental and health regulations have at times prevented the use of hazardous but fast-curing stealth coating adhesives in favor of less toxic materials, lengthening maintenance tasks. According to industry executives, increased anti-tamper requirements and the intersection of ITAR regulations with global supply chains also contribute to program complexity.[33]

Increasing aircraft cost. In an analysis of the underlying reasons for cost escalation in defense aircraft, RAND found that aircraft cost rose at an average annual rate of 7% to 12% (depending on aircraft type) between 1974 and 2005.[34] This was more than double the rate of economic inflation over the same time period. The effect on the fighter segment illustrates the magnitude of the trend: compared to the 1980s, from 2001-2010 the Air Force spent 55 percent as much money to get 10 percent as many fighters.[35] Analysis by the Teal Group has shown that while DoD tactical aircraft procurement quantities have held steady around 50 aircraft per year, procurement costs doubled (in constant FY14 dollars) from slightly less than $5B per year in 2000 to more than $10B per year between 2008-2012.[36] Further, RAND found that customer (government) driven factors accounted for more cost growth than the rate of inflation for four of the eight pairs of systems studied (impacts varied widely between 2% and 12%).[37] Customer driven factors that drove substantial cost increases included "technical characteristics of an aircraft, procurement rates, and complexity of the airframe."[38]

Accurate cost estimating early in a program is also more difficult with increasing complexity. For example, the estimate of average F-22 unit cost tripled between 1992 and 2004.[39] Similarly, the target cost of a single F-35A more than tripled since the JSF program office was established: $43M in 1994, $91M in 2001 (source selection), and $139M in 2012 (all year 2013 dollars).[40]

Infrequent new programs. Decreasing frequency of new program starts may induce firms to exit an aircraft market segment rather than pay the high cost of keeping design and production capability viable through internally-funded activity. Additionally, decreasing program frequency has also reduced aircraft diversity. For example, the number of fixed wing fighter aircraft types in the USAF inventory has steadily declined from a peak of around 12-15 types in the 1970s to four types today.[41] This decreasing number of aircraft types has been paralleled by industry consolidation, keeping the number of new manned fixed-wing development efforts per prime contractor relatively steady at around one per decade since the

[1] Negative properties or behaviors only observed when all elements of a complex system are operating together

1970s.[42] But any further industry consolidation and reduction in aircraft types in some segments will result in a monopoly market.

Acquisition system complexity. The high complexity, cost, and very long development cycles of military aircraft have fostered a complex and inefficient acquisition system. As acquisition organizations and processes grow, levels of hierarchy are added and modularity is increased to manage increasing scale and complexity. High cost also invites significant oversight from Congress, the media, and the public, requiring more external communication and taking time away from program and technical management. This adds nodes of communication and decision making, exponentially increasing lines of interaction and associated coordination burden. A recent MIT study concluded that DoD's defense acquisition is well into a region of declining marginal returns and diseconomy of scale, where each incremental investment in the system produces less and less additional productivity.[43]

This complexity in the acquisition process creates a high barrier to industry entry, as significant resources, political relationships, and process knowledge are required for a firm to successfully navigate DoD's acquisition enterprise. Additionally, the many years required for conceptual design, product development, and production may span multiple pendulum swings in government policy, political support, and acquisition paradigms. Non-aligned PPBE, JCIDS and Acquisition processes exacerbates the problems of long development timelines. This creates further acquisition complexity, as a program birthed in one policy and acquisition environment may have to depart from its foundational assumptions and structures a decade later, while still in development.

Consolidation and teaming. Reduced defense spending after the Cold War drove much of the industry's consolidation, exacerbating the downstream effects of aircraft complexity on program infrequency. Teaming between firms on specific programs has also been employed as a means of surviving and winning in this environment. Firms team with other firms in bidding for aircraft contracts when they assess that *alone* they cannot handle 1) the program's complexity (design, production, integration), 2) the acquisition system's complexity (politics, relationships, process knowledge), and/or 3) the business risk of losing a competition in an environment of large and infrequent programs. In spite of the enormous size of today's aerospace defense firms, teaming is increasingly common—all three of the most recent fighter programs were won by teams (F/A-18E/F and EA-18G, F-22, F-35), as well as the V-22. While teaming is often justified from a firm's perspective, it exacerbates the problem of diminished competition produced by industry consolidation.

Innovation Shifting Down the Supply Chain. With aircraft prime contractors largely focused on system integration and final assembly, lower tier suppliers have become more critical to the process of innovation. While the primes can drive innovation at the system level and higher (e.g. combinations of components, new operational concepts, system of systems development), significant innovation in aircraft capabilities derives from advances in critical

subsystems like radar, datalinks, electronic warfare, propulsion, weapons, and human interfaces. The ability of a prime contractor to manage and drive supplier innovation is a need that has grown over the past 20 years.

One risk in this development is that primes face cost and schedule risk when they integrate supplied subsystems and assemblies because they lack detailed understanding of the relevant technology. Further, primes face an increasing burden to track supplier risks as subsystems are developed, so that overall project risks are managed at the system level in a proactive manner rather than reactively when delivery dates are missed. Effective global supply chain integration therefore is a key factor in program success.

Consequence of these trends: JSF acquisition and industrial model

Industry trends described above have continued to grow in amplitude, culminating in the Joint Strike Fighter program. Aircraft cost, complexity, and the simultaneous recapitalization needs of all three military services paved the way for a program designed to achieve significant cost savings via economy of scale and design commonality. To this end, the JSF was designed from the start to be not only multi-role but joint, and not only joint but international in development and production work-sharing. As industry analyst Richard Aboulafia quipped, "F-35 can almost be regarded as much an industrial policy as a fighter."[44]

Characteristics of the JSF acquisition and industrial model:

- Affordability via economy of scale (in development, production and sustainment)
    - Very large joint and/or international market aggregation
        - Multi-role platform
        - High design and component commonality across variants
        - Requirements driven by diverse users
    - Global supply chain with PBL sustainment
- Simultaneous recapitalization of multiple aircraft designs/platforms
- Winner take all program competition

As effects of the JSF program on industry emerge, the key question is whether JSF is a flawed acquisition/industrial model or merely an execution challenge. DoD's answer to this question has deep implications for the industrial base and future acquisition programs such as Future Vertical Lift. Predicted benefits of the JSF model are analyzed next, along with consideration of risks and implications for industry structure and competition. The emphasis of this analysis is not on the F-35 as an aircraft, but on the broader JSF model of acquisition and

logistics. The F-35's performance relative to specific threat environments therefore is beyond the scope of this analysis.

The road to JSF. Instead of staggered fighter programs with continuous moderate spending, incremental technology progression, and multi-firm competition, government decisions over time have created an environment of increasingly extreme feast/famine procurement cycles of long duration. Failure to recapitalize the fighter fleet in the 1990s was followed by unprecedented spending on the F-22 program for relatively few aircraft (Figure 4). This motivated the simultaneous recapitalization of the bulk of our fighter force via the JSF. As James Fallows described it in his telling of the JSF story, "This situation became known in the military as the tactical-aviation train wreck. The Air Force was trying to buy more F-22s, the Navy was trying to buy its expensive new airplanes, the Marines wanted something different—and no one imagined that there was enough money to satisfy all their demands. Meanwhile, the existing fleet kept getting closer to the end of its projected service life."[45]

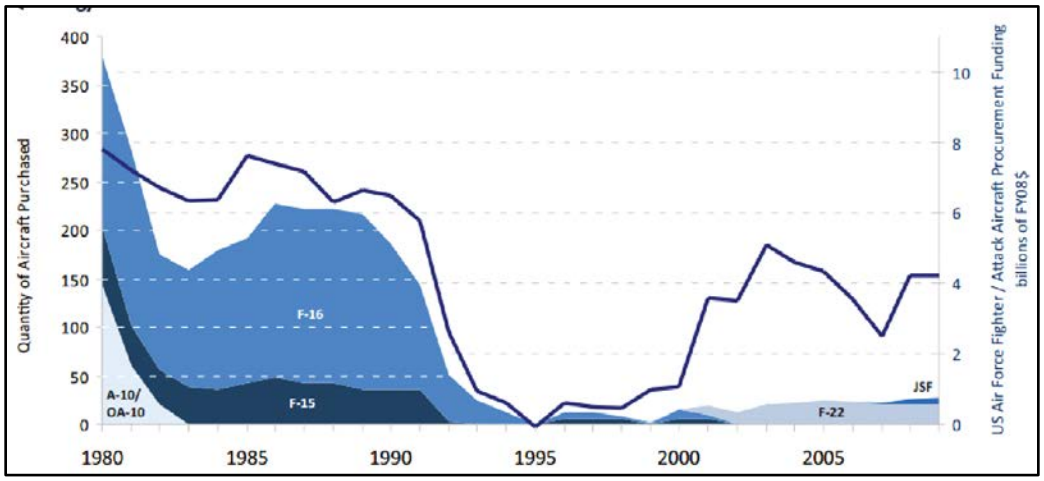


Figure 4. U.S. Air Force Fighter Procurement: Spending and Quantity[46]

Together, the F-22 and F-35 can be viewed as the continuation of historical patterns of platform pairings taken to an extreme. The F-15A/C was an expensive single role fighter with moderate production quantity and exported to relatively few nations due to high price and capabilities. It was followed by a less expensive, multi-role, and highly exported fighter with large production volume—the F-16. Decades later, the pattern is repeating with the F-22 as expensive, limited, non-export, single-role fighter, and the F-35--a less expensive, multi-role, highly exported fighter. But cost, complexity, and an anti-access threat environment have pushed the pattern to extremes, resulting in a JSF program of sufficient scale to permanently change the industry. Assessing whether this change will strengthen or weaken national security requires analysis of the benefits and risks of this model.

Arguments for the JSF model. The case for the JSF was primarily one of affordability bolstered by urgent domestic fleet recapitalization needs and the benefits of multi-national interoperability. Partly out of reaction to the F-22 cost-quantity death spiral, in which performance was prioritized at almost any cost to the detriment of quantity, the F-35 program would prioritize cost over performance. This emphasis was manifest early in the program, when JSF leadership traded the adjective "advanced" for "affordable" in describing the program's ambitions.[47] Affordability would be achieved via economy of scale and commonality of design, production, supply, and sustainment.

Commonality has long been sought as a panacea for rising fighter costs, but has repeatedly proven difficult to achieve to the degree hoped for in program cost estimates. The F-16 and F-18 began as a joint program with a 100% commonality goal, as did the A-7D and A7-E, variants of the F-4, and descendants of the TFX program (A-10, F-14, AV-8A, A-7). In each of these programs, service-specific needs eventually drove commonality below 40%, and in some cases to zero.[48] Although the F-35 program will very likely achieve higher commonality than these joint programs of the past, a 2013 RAND study asserted that there will be no life cycle cost savings compared to three separate service-specific programs.[49] So while the benefits of commonality in F-35 erode as the program progresses, the disadvantages of the JSF model remain (discussed below).

Economy of scale will deliver a cost benefit that largely depends on how many F-35s are procured globally, as domestic joint programs have been shown to save only 3% in life cycle cost over single-service programs.[50] But even if JSF economy of scale does bear fruit, it will have amounted to a trade between cost and the risks of homogeneity, which are serious and often overlooked.

Risks and disadvantages of the JSF model. The U.S. fighter fleet today is large and diverse. But when current 4th generation aircraft begin retiring, homogeneity will increase quickly as F-35s replace sunsetting programs. The risks of a homogenous fighter force are of four types: 1) single-point failure vulnerabilities, 2) design compromises, 3) loss of high/low fighter exports as foreign policy and economic tool, and 4) impacts of loss of competition in the industry.

Single-point failure vulnerabilities occur during non-combat operations but also present an opportunity for adversaries. The options available for defeating a fighter aircraft via hard kill or mission denial span the spectrum from attack by tactical aircraft to surface-to-air missiles to cyber attack. The cost and schedule required to build aircraft that match or exceed the capabilities of U.S. fighters drives adversaries toward asymmetric options. If an adversary finds one critical weakness in the F-35's design that can be exploited, it could build a jet or missile that is inferior in every other way except for its ability to capitalize on that weakness. Alternatively, the F-35's signature in multiple frequency bands might be characterized and leveraged by surface to air missile and early warning systems for long-range detection.

Additionally, the JSF model's global supply chain and network-based maintenance processes may increase vulnerabilities. If the Autonomic Logistics Information System (ALIS) were successfully disabled by cyber-attack, it could cripple the majority of our fighter fleet.[51] Alternatively, if supply of critical components from the JSF's far-reaching global supply chain is not effectively protected, an adversary could cause significant disruption at relatively little expense.

Adversary actions aside, single-point vulnerabilities from a maintenance and safety perspective also increase in a homogenous fleet. In the last 10 years, diverse safety concerns grounded the F-15 fleet for two months and the F-22 fleet for four months. F-18s and F-35s have likewise been temporarily grounded over airframe and engine cracks. It is also common to stand-down aircraft after flying accidents until mechanical or fuel problems are ruled out as causal. Groundings such as these do not cripple a diverse fighter force, but would take a homogenous force out of the fight.

Design and performance compromise is a necessary ingredient in multi-role and joint aircraft programs, as commonality requires each customer to accept performance and risk penalties for their unique mission set. But the trade-offs required to accommodate the Marine's STOVL version into JSF likely pushed this paradigm too far. The F-35A has 30% higher wing loading and significantly lower thrust to weight ratio than typical air-to-air capable fighters, resulting in poor performance in a turning fight. While an opposing fighter would ideally be killed beyond visual range, historic air-to-air missile kills overwhelmingly have occurred in the visual arena.[52]

Further, F-35 design compromises require some features and components required by one service to be carried on all versions, creating extreme emphasis on weight reduction in the development phase. This leaves little structural or weight margin for capability growth and modernization, a tool widely used in previous fighter generations to maintain the advantage over an evolving threat. Some have argued that excess space, weight, power, and cooling capacity should be required as a Key Performance Parameter to encourage industry to build performance margins into proposed designs, enabling upgrades to the aircraft's capabilities over time.[53] But the JSF model is moving paradigms in the opposite direction.

A **high/low aircraft mix** has operational as well as strategic and foreign policy advantages. The F-15/F-16 pairing gave the U.S. Air Force the benefit of dominant air superiority capabilities while simultaneously providing an affordable multi-role fighter for strategic partners. And as the F-16 grew in cost and capability over time, it created an even wider spectrum of cost/performance options for export customers. But tomorrow's high/low mix presents several difficulties. First, the F-35 is so expensive that, although it occupies the "lower" floor in the F-22/F-35 mix, many partners may not be able to afford it. Further, a single fighter export option does not enable the U.S. to manage often precarious international relationships via tiered product offerings, as it has in the Middle East.[54]

Competition in the aircraft industry has proven vital to U.S. technology advancement and product/process innovation. The single greatest impact of the JSF acquisition model is that it is fundamentally altering the structure of the fighter industry in four ways: 1) effectively ending competition in the domestic market, 2) squeezing the life from Europe's fighter industry, 3) guaranteeing fighter dependence from our Asia/Pacific allies, and 4) synchronizing the recapitalization of previously staggered U.S. fighter programs. The result is likely to be domestic monopoly, inefficiencies of a program too big to fail, and even longer time gaps between new fighter programs.

Innovation is best fostered by interleaved periods of technology advancement and observation of product use. Staggered fighter programs create such an environment, where competing firms/teams are repeatedly designing, producing, feeding off of a competitor's innovations, and incorporating lessons learned from one design into the next. Under the JSF model, new fighter programs will be so infrequent that design and production engineers will be fortunate to work on even one new design during their entire career. And decades between recapitalization programs nearly guarantees that users will demand even greater leaps in performance, continuing the performance-complexity-cost spiral evident today.

In sum, **decreased industrial and aircraft flexibility in capability and capacity** are the fundamental risks of the F-35 model, things we should be loath to concede in a fast-changing and uncertain environment. Diversity of fighter platforms across the services provides a hedge against operational, maintenance, and safety risks that could severely limit operational availability of fighter air power. A portfolio of platforms complicates adversary attempts to exploit weak points, and provides the U.S. the flexibility to meet unforeseen challenges.[55]

JSF industrial model for future programs. DoD's pursuit of large, common-platform programs results in "all or nothing" competitions that could increasingly drive losers out of market segments. Domestic monopoly is already present in strategic tankers, imminent in fighters, and probable in the near future for bombers and rotary wing aircraft, as program decisions are made in the next five years that will affect the structure of those markets for the long term.

The Army's Future Vertical Lift[2] (FVL) appears to be following the JSF acquisition model, with potential for similar negative industry consequences. First, FVL envisions developing scalable technologies to satisfy a wide range of roles, from armed scout to heavy cargo transport. Similar to the JSF approach, it seeks to develop as much commonality as possible among variants but it is unclear whether the Army intends to procure one airframe for these roles or two.[56] If a single prime is selected, the loser will be excluded from a multi-decade effort to replace over 4,000 utility, attack, and potentially heavy lift aircraft in the DoD

[2] Much like the JSF's recapitalization of multiple fighter lines, Future Vertical Lift is a program designed to leverage commonality in replacing the U.S. Army's UH-60 Black Hawk, AH-64 Apache, CH-47 Chinook, and OH-58 Kiowa.

inventory. Sustaining even a single viable competitor to the winner throughout such a period seems unlikely.

5. GENERAL FIRM STRATEGIES

This section presents a general description of the strategies discussed during firm visits in early 2014: more specific observations by market segment and platform are presented in following sections.

Strategy Development

U.S. defense aircraft industry firms have responded to the downturn in defense spending with strategies based on differing models and of varying rigor. In some cases it was apparent that firms employed little strategic assessment processes and primarily reacted to conditions as they occurred. But most firms employed some variation of the following basic strategy development process.

Assess the situation: Many elements comprise the assessment, including: identify market or business under consideration; forecast future market revenues under different scenarios; assess firm position in the market including status of existing product lines; assess competitor positions in the market; determine status of suppliers and their position relative competitors; identify positions of key stakeholders.

***Determine goals*:** This is firm dependent, but in general captures the value the firm seeks to generate in a particular situation. Business value is typically measured through growth in various measures of financial performance, some of which include return on investment, cash flow, debt to equity ratios, revenue growth, and earnings. Depending on assessment of risks, or degree of uncertainty, goals may be defined conservatively or aggressively.

Establish concepts for reaching goals: This is basically synonymous with the business model used by the firm to forecast potential measures of the goals. For example, if the goal is to win a new development effort, the concept may be to sacrifice short term profits in development for the opportunity to make money in production or sustainment.

Develop policies to support concepts: Once a strategic decision is taken, this is where implementation occurs at the institutional level with the necessary direction, policy, or guidance developed to support implementation of the concepts.

Develop actions to execute the strategy: Business strategy is often more "tactical" than generally viewed within government, and the actions taken to implement a strategic decision matter as much as the decision and policies themselves. It is at this step that firm and government interest divergence may be most visible, increasing the importance of government and industry communication early/frequently enough to influence mutually beneficial strategy formation.

Strategy in Defense Conglomerates

As identified by business analyst Michael Porter, there are two basic types of competitive advantage: cost advantage, and differentiation advantage.[57] In a broad market, firms can either seek to offer products at a lower cost than their competitors (**cost leadership strategy**), or they can seek to deliver products that are superior in the eyes of the customer (**differentiation strategy**). Firms competing on price or differentiation in a narrow market segment are said to be pursuing a **focus strategy**.[58] While Porter suggests that these three strategies are not compatible with one another, modern conglomerates often employ multiple strategies by creating separate business units.[59] This approach is common for defense aircraft manufacturers, with implications for government understanding of firm behavior.

Strategic Implementation of Portfolio Management

Domestic defense aircraft firms often are business units of larger conglomerates which employ a portfolio mindset in managing subsidiaries or subordinate business units. Conglomerate strategy is therefore significantly based on current and desired portfolio balance. For example, Boeing's portfolio includes commercial aircraft and defense/military systems, while Lockheed's portfolio is almost completely defense focused. Boeing is therefore able to mitigate the effects of a defense downturn with its commercial businesses, while Lockheed has different strategic options given its defense focus. In spite of these differences, firms have four general options available to them during a defense downturn:

Portfolio Option #1: Maintain existing business. This option focuses on maximizing performance of existing product lines and programs, such that the firm's market share will increase accordingly as other firms lose business in a defense downturn. For example, Lockheed Martin has publically stated the strategic importance of properly executing existing programs, (especially F-35) as a way to hedge against potential decreases in future order quantities due to schedule delays or cost increases.[60] A risk of this approach is the lack of emphasis on innovation for future growth, but it may be the best achievable strategy with available resources.

Portfolio Option #2: Expand existing businesses. Firms use this strategy as a low risk approach to growth, as it builds on existing competencies. Given the current environment of reduced government budgets, every firm visited in this study employed some variation of this strategy for expanding some combination of commercial or foreign sales.

One variation of this option is to take an existing product line and expand it to a new market or customer. A second is to develop a new product line within an existing business to capture new customers or markets. This approach seeks to grow value via expansion based on existing competencies. For example, a firm be in the reconnaissance aircraft business with an existing production line. In the first variation, the firm seeks to win new orders for the existing aircraft from new customers such as civil law enforcement. In the second variation, a firm in the fighter aircraft business may seek to develop a new fighter design to capture new sales.

A defense aircraft firm may see expansion into commercial or civil markets as expansion of existing business, or it may consider it creation of a completely new business, depending on the commercial experience of the firm and the similarity of the commercial product to its military baseline.

Portfolio Option #3: Expand into new businesses. A firm use this strategy to develop a new business outside its existing competencies. For example, a firm with divisions for aircraft manufacture may choose to diversify by establishing or acquiring a new business unit in software development. Or, a firm focused exclusively on manned platforms may choose to enter UAS markets that require new competencies and resources. For defense firms, this approach typically includes expansion into commercial or civil market sectors where the differences in product lines or use is disparate enough to require significant design changes from any existing military systems. Expansion into foreign markets may fall into this category for some firms, depending on their existing foreign sales and degree of design change required.

This is option often is riskiest, especially in an era of declining budgets. But it offers the most potential for a firm's innovation and future growth, and is an obvious avenue for growth for defense firms given reduced DoD budgets.

Portfolio Option #4: Exit a business or market. Exiting a business or market may free capital for pursuing a more attractive business opportunity, or the cash may be distributed to ownership as a way to generate value for them outside of company growth. Because market exit eliminates future value growth from the firm, it is usually exercised as a last resort, and has significant implications for the U.S. government when employed in defense markets.

Other Implementation Strategies

Mergers and Acquisitions (M&A): The use of mergers and acquisitions (M&A) to enter new businesses was a common approach, although recent M&A activity has not been as prevalent as in the last downturn due to the large degree of consolidation that already existed when the most recent downturn started. In some cases, M&A was used to expand existing businesses or product lines where the acquired company complemented existing product lines with higher technology or less costly alternatives. M&A can also be used to consolidate supply chains, increase the corporate base for production and R&D, or reduce competition (with government approval).

Partnerships and Joint Ventures: Partnership and joint ventures are prevalent throughout the global aircraft industry, including domestic defense aircraft suppliers and primes. Partnerships can target vertical or horizontal integration (to include partnering with rivals), in R&D or future product development. During uncertainty, they enable risk sharing and hedge against unforeseen outcomes. Teaming arrangements already announced on programs such as T-X, FVL, and LRS-B reveal that firms view them as a strategic means of securing revenue, sometimes choosing strong partners that would put losers out of a business in all or nothing

competitions. Further, partnerships can be developed outside of defense or aviation to expand the menu of offset options or diversify corporate product lines.

Expand analytical efforts: Some firms pursue expansion of internal analytical efforts and academic/government engagement to refine assessments of market risk and opportunities. Primes such as Boeing, Lockheed or Airbus must conduct their own assessments to discover opportunities and downside risk that may not be directly articulated by main buyers. Second tier and lower suppliers likely rely on primary contractors' stated and projected demands for their components.

Influence customers: With a monopsony buyer in most defense markets, firms seek to enhance market demand by influencing customers' threat assessments, operational constructs, and related aircraft requirements. In the case of the Asia-Pacific rebalance, where operational concepts such as expeditionary basing or "island-hopping," or the role of mobile ground forces remain immature, firms can influence the conceptualization of the realm of the possible, creating new demand signals for their products and services.

Supply-chain management: A continuing trend is enhanced production efficiency through more efficient supply-chain management. As defense aircraft demand tightens, large primary contractors such as Boeing with a wide range of operational options may increase their leverage over second and third-tier suppliers, increasing profit margins by gaining pricing and delivery concessions. Such options must be weighed against the risk of damaging what may be an increasingly fragile supply base.

Increase research and development: This allows firms to potentially gain advantage in future markets. Boeing, for example, may advance efforts to position the 777 aircraft as a viable platform for the KC-Y (or follow-on aircraft). Others may work to develop new airframe forms such as a blended wing/lifting body, to hedge in the potential demand for a more efficient or stealthy air mobility platform.

Expand Maintenance, Repair and Overhaul (MRO): MRO operations represent an increasingly important revenue stream, particularly as new development and production efforts decrease during declines in government spending. Boeing and Lockheed have clear advantages in this area and are actively pursuing this business.

Seek government assistance in Foreign Military Sales (FMS): Since export of military technologies is government controlled, seeking assistance is a natural consequence of the relationship. This includes Foreign Military Sales (FMS), export advocacy, trade agreements and regulatory actions to enhance exports. Similarly, should another round of defense industrial base consolidation be considered necessary, a permissive anti-trust environment would expand on the options available to corporate leadership.

Emphasize "value" over low cost. Notably, as many firms discussed growth opportunities in foreign or commercial markets, they typically characterized their competitive

advantage as being able to offer products with more capability than their potential competitors, but at a "slightly" higher price. In essence, the growth strategy hinged on a value proposition that sought to differentiate firm product offerings by performance gained for price paid. In all cases, U.S. firms sought to position themselves as the "high end" provider. While this strategic approach is in line with historical experience of the firms as suppliers to the U.S. government, it may not represent the best strategic approach moving forward. Foreign buyers are often more sensitive to price considerations than the U.S. government, and if the strategic approach of the U.S. government changes to account for new demands in the Asia-Pacific that require higher quantities with an affordability emphasis over technological advancement, the lack of firm focus on innovations that drive reduced cost may prove to be a strategic miss on two fronts.

6. WHAT GOVERNMENT NEEDS FROM INDUSTRY

In DoD's October 2013 assessment report on industrial capabilities (October 2013), the Department provided an overview to Congress of the health of the defense industry. In assessing various industrial sectors, the report described a healthy industry as one that can respond to immediate national security needs while addressing emerging threats and preparing for future demands.[61] Further, the report emphasized the importance of a market based approach that "continues to produce innovative ideas, products, and systems that remain the envy of the world."[62] Implied in a "market based approach" is the principle of competition, although the report admits that this isn't always possible to achieve through government policies and programs. While describing a healthy industry as one that meets national security needs is satisfying from a conceptual perspective, it lacks detail in providing factors for analysis.

Characteristics of a healthy aircraft industry

Based on a review of DoD's report and discussions with industry and analysts, the following four factors are offered as representative of a healthy defense industry and are best applied in analysis of the defense aircraft industry by aircraft market.

Technology dominance through innovation. A healthy U.S. industry produces technological innovation that is the best in the world. This is one of the explicit goals of a competitive policy, but is not necessarily a given in every market. This factor supports the American way of war that has historically relied on technological supremacy over quantities of war materiel. The ability to innovate is also a key feature of a healthy industry and economy able to grow to meet new demands with scarce resources.

Affordability. The other explicit goal of a competitive policy is to achieve the lowest price for the technology available. Together with the goal of world leading technological development, this factor places value on innovations that lower cost, and is a key means that firms use to differentiate their products in global markets.

Competition. Without fail, the key feature mentioned first in any discussion of a healthy U.S. industry is the need for competition. Degree matters: a monopoly supplier is better than no supplier, a duopoly represents the minimum degree of acceptable competition, and multiple suppliers represents the most desirable state (oligopoly). The implication for national security is that domestic suppliers are preferable to foreign ones, but as previously developed and acknowledged in DoD's industrial capability report, the global nature of the defense aircraft supply chain comes presents risks that must be managed because they cannot be eliminated.

In pursuing a market based approach that emphasizes competition, U.S. policy relies on accepted economic theory that competition promotes the most innovation at the lowest cost. While generally accepted by economists as true, research has shown that the number of suppliers necessary to optimize innovation varies with industry and depends on many factors.[63] In general, monopolies do not engage in much innovation because they don't have to in order to

maintain market position, and at the other extreme in markets with a large number of suppliers (perfect competition), the incentive to engage in innovation is also reduced since little profit exists to fund research and spillover effects are presumed to dominate.[64] An oligopolistic market is considered ideal, but the sensitivity of innovation to the number of competitors in an oligopoly is difficult to assess.[65]

Exportability via high/low mix of product offerings. A key national security interest is providing security for our allies and partners. As previously developed, a key enabler of this aspect of foreign policy is industry's ability to provide a spectrum of system cost & capability options for sale to our strategic partners.

Capacity. Government's needs for aircraft quantity change over time, depending on conflicts, threats, and budget pressures, requiring an industrial base that can flexibly respond. But system complexity, workforce development, long lead times for parts, and long contract development timelines make it very difficult for industry to change capacity quickly. This issue is explored in more depth in section 8.

In summary, the ability of industry to meet these core government needs is heavily influenced by government policy and practice. This report's remaining analysis of the defense aircraft industry leverages these factors in considering convergence or divergence of industry and government interests and needs.

7. ANALYSIS BY MARKET SEGMENT

Fighter Aircraft

Aircraft complexity, acquisition process complexity, affordability goals, and government acquisition decisions are driving the U.S. toward a monopoly fighter market with implications for future affordability, technological innovation, combat effectiveness, and operational risk. The U.S. fighter aircraft industry differs from other aircraft segments in several ways. Fighter programs epitomize the extreme in development time, expense, and high technology, and are among the most widely recognized symbols of a nation's military power. They are not commercially derived and have minimal commercial spin-off potential compared to other platforms. These factors combine to create an industry characterized by intense national resource debates, high inter-service tension, strong political interest, and high acquisition complexity.

Fighters: Historical trends.

Key terms employed in description of historical dynamics include three types of capabilities resident in aircraft firms. **General capabilities** include the design and manufacture of aircraft in general.[66] **System-specific capabilities** are those required to design and produce a specific class of aircraft, normally arising from experience with that class (such as fighters). Lastly, **firm-specific capabilities** are those possessed by a specific firm that set it apart from other firms and are not necessarily associated with a specific class of aircraft. Stealth technology in 1970s and 1980s was a prominent example of a firm-specific capability.

During the first period of post-WWII fighter development, from **1945 through the late 1950s**, more than a dozen firms were capable of producing fighters, and the revolutionary change from piston to turbojet engines spurred significant innovation.[67] Firm-specific capabilities proved vital to rapid advances in technology and performance, enabling new entrants like McDonnell and Convair to capitalize on their expertise in non-fighter supersonic flight and weapons system development to attain top positions in the fighter industry.[68] Speed, climb rate, payload, and ceiling were prioritized over maneuverability and reliability, and many diverse firms competed in prototyping and producing fighter aircraft.[69]

By contrast, during second period (early **1960s to mid-1970s)**, system-specific capabilities dominated as slower technology rate of change prevented new entrants from harnessing large innovation to break into the industry. Consequently, industry-leading firms in the late 1950s held their positions into the 1960s and 1970s, and exiting fighter firms were not replaced by new entrants (Figure 5). The Pentagon consolidated R&D efforts into fewer aircraft programs and shifted focus from fast/heavy multi-role fighters to light/agile air combat fighters.[70] When cost savings of single role aircraft were not realized, momentum moved in the direction of even smaller and less expensive fighters. But a tendency toward greater complexity

was soon evident in these aircraft as well, as they gained weight with each added role, and new program start frequency decreased significantly.

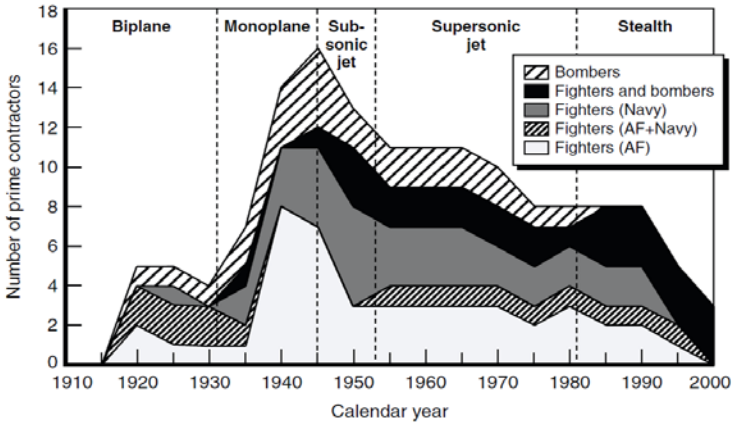


Figure 5. U.S. Combat-Aircraft Firms and Principal Technology Eras[71]

Firm-specific expertise returned to prominence during the third period (**1970s through the 1990s)**, as disruptive technologies once again enabled new leaders to emerge in the industry. Stealth technology revolutionized aircraft design and development. Lockheed and Northrop emerged from their non-fighter and largely cloaked product years to command leadership in stealth technology, resulting in the F117, B-2, and F22.[72] Post-Cold War budget declines triggered industry consolidation which reduced the number of fighter firms from eight to only two (Lockheed Martin and Boeing) with a parallel progression toward few fighter programs (Figure 6).

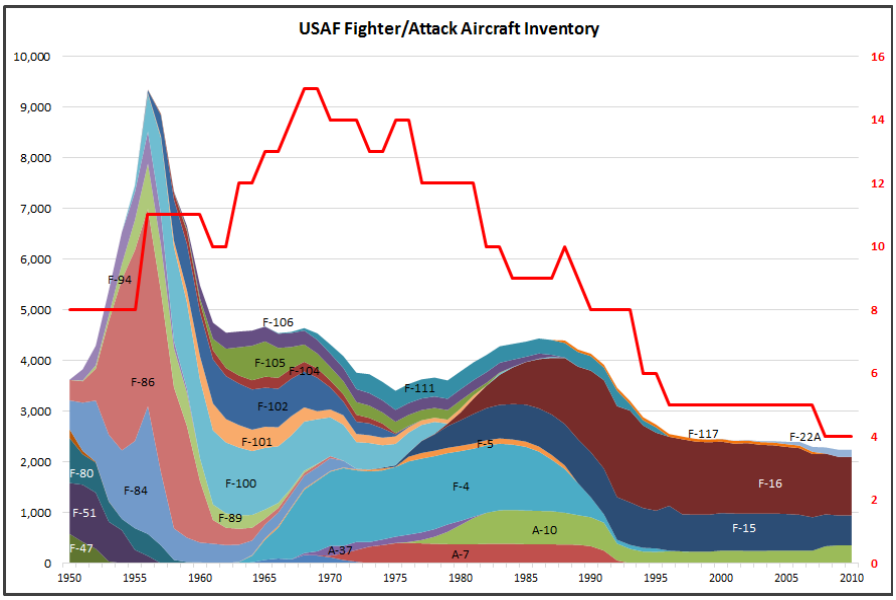


Figure 6. U.S. Air Force fighter/attack aircraft inventory 1950-2010[73]

New Era in the Fighter Aircraft Segment

A fourth period in the U.S. fighter industry is likely now emerging, characterized by a monopoly market, "system of systems" cross-platform and cross-segment interdependencies, and a shift in emphasis from maneuverability, speed, and high frequency stealth to affordability, multi-spectral[3] stealth and sensors, and net-centric battlespace integration.[74] The F-35 demonstrates some aspects of this shift, as it is less maneuverable and slower than the F-22, is not as stealthy, and carries half the number of air-to-air weapons.[75] In place of premium air-to-air capabilities, the less expensive F-35 possesses primarily strike capabilities, a higher fuel fraction for greater range, and infrared detection/targeting capability. But just as sensors on U.S. aircraft leverage more of the electromagnetic spectrum, the capabilities of adversary systems likewise are expanding. Infrared Search and Track systems (IRST) are common on many foreign fighters, and U.S. high frequency stealth capability is inducing adversaries to design sensors that employ longer wavelengths for target detection. In turn, this technology will likely drive the U.S. to design future aircraft for survivability in a multi-spectral threat environment.[76]

System of systems interdependencies. As stated in DoD's Joint Operational Access Concept, the U.S. must achieve "complementary vice merely additive employment of capabilities in different domains such that each enhances the effectiveness and compensates for the vulnerabilities of the others."[77] Such capabilities require DoD to advance beyond the current "family of systems" paradigm, in which independent systems provide similar capabilities or achieve complementary effects. Instead, DoD is increasingly developing and acquiring "systems of systems," in which otherwise independently useful systems work together to provide unique capabilities not provided by any of the constituent systems individually.[78]

This architecture leads to acquisition and operational interdependencies that increase system and enterprise complexity in multiple dimensions. User requirements for one system are connected to those of other systems, doctrine and tactics must account for operational interactions, and an already complex acquisition system is further stressed. For example, budgeting and requirements processes which are not time-aligned will have to support acquisition of platforms whose value depends on complimentary but independently procured systems.

Net-centricity: fighter as non-traditional ISR asset. The system of systems approach to warfare requires significantly increased information sharing between nodes, enabling capabilities such as cross-domain cueing.[79] Because fighter aircraft fly deeper into contested areas than do traditional ISR platforms, information collected by fighter sensors will be increasingly shared with other systems and users in the battlespace.[80] Paradigms are shifting to such an extent that some envision a highly interconnected ISR/strike/logistics network that operates as a unified and highly connected "combat cloud."[81] In this context, the head of the U.S. Air Force's Air Combat

[3] Referring to a combination of radar, infra-red, and/or optical wavelengths

Command suggested that we think of 6th generation fighters not "in form factor terms," but in terms how they integrate into and enable the combat cloud.[82] This future is likely to accelerate the blurring of platform categories, a concept which will be explored later in this paper.

Monopoly market. Finally, this new period in fighter development will be significantly shaped by monopoly in supply, as Lockheed Martin is likely to become the sole integrator of fighter aircraft in the U.S. F-22 production was terminated in 2012, and the three 4th generation fighter lines are forecast to go cold within the next four years.[83] Boeing's F-15 line will remain active until 2018 with current orders, and its F-18 line until 2017. Lockheed is completing F-16 orders for Oman and Iraq, and will also cease production by 2017 unless new sales are obtained.

Key Factors Shaping the Fighter Aircraft Industry

The fighter market is the most prominent example of the effects of high user requirements, aircraft complexity and cost, and decreasing program frequency (Figure 7). These and other factors shaping the U.S. fighter aircraft industry are presented at length in a previous section of this paper, along with causes and implications of a monopoly domestic market ("Trend #4 and JSF model).

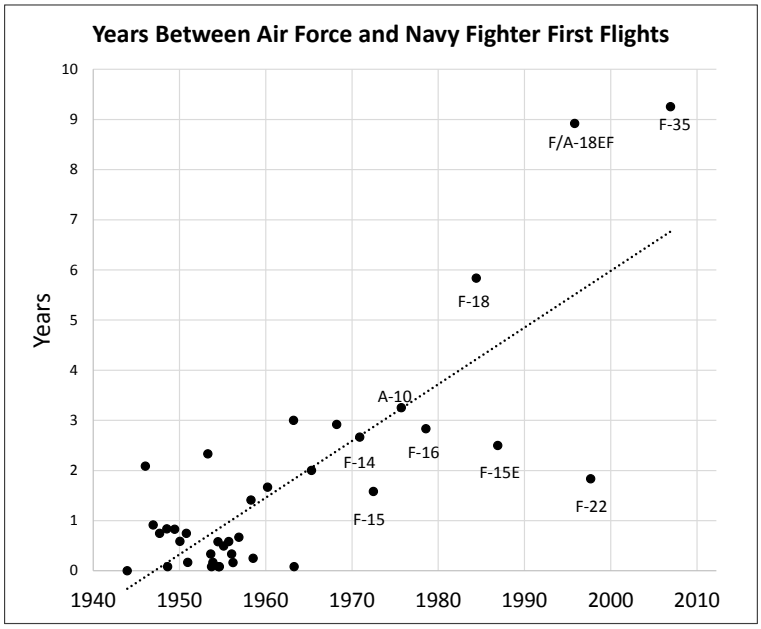


Figure 7. Years between each fighter first flight and the previous first flight [84]

Fighter Export market. During domestic budget downturns, defense firms predictably pay increased attention to foreign markets. The primary foreign markets able to afford expensive U.S. fighters are Europe, the Middle East, and Asia/Pacific. But Europe and other key allies including Israel, Australia and South Korea have already committed to the F-35. And Gulf Cooperation Council states are currently making their last fighter purchases for the foreseeable

future, with F-15s going to Saudi Arabia and F-16s to UAE. Qatar will likely make the last significant purchase in the region for some time.

This leaves Asia/Pacific, which is a much more difficult market due to smaller budgets, cultural differences, maturing acquisition processes, and offset requirements. Some Pacific allies may shift a portion of funds previously marked for fighters to maritime patrol and airborne early warning aircraft.[85] Additionally, China's decreasing defense import-to-procurement ratio indicates that Russia will have to more aggressively seek sales in other places, increasing competition for U.S. products in nations like India.[86] But industry interviews conducted in April 2014 indicated that U.S. firms have been late in developing serious Asian sales relationships. These factors, combined with lack of brick and mortar presence in the region, mean that the future of U.S. fighter exports is far more challenging than the past, and firms will be highly dependent on U.S. government pressure to achieve further sales.

The most significant factor affecting the future of U.S. fighter exports is the F-35 program. Boeing's F-15 line has little hope of survival beyond the Saudi deal and the F-18 must win Kuwait, or Malaysia, or be gifted a stop-gap domestic purchase in order to remain in production. Meanwhile, Lockheed Martin is rejuvenating its 4th generation export ambitions with the F-16V, which must compete against the similarly priced Gripen (the only European line with a chance for longevity given its win in Brazil[87]).

If these 4th generation fighter lines close, the U.S. will lose its historic high/low mix of fighter offerings to the international market with implications for foreign policy options, economic ties, and regional security partnerships. Figure 8 depicts the future gap in export fighter price offerings relative to the price point sought by international markets.

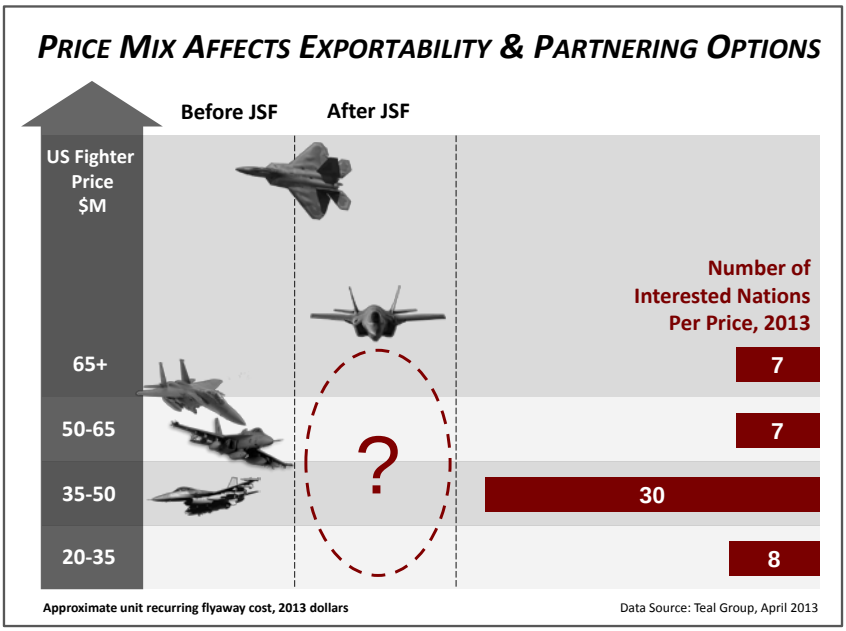


Figure 8. Erosion of high/low fighter export offerings

Fighter Upgrades

Domestic upgrade market. While U.S. military power relies on development and procurement of new weapon systems (including aircraft) on a scale not yet matched anywhere on the globe, a second pillar of U.S. military dominance is continual upgrade and modernization of existing weapon systems. The extreme example of this is the Air Force's bomber fleet, with B-52 and B-1 bombers now performing CAS missions with targeting pods and weapons originally developed for fighter aircraft. Likewise, fighters are modernized in response to evolving threats, and airframe life extensions are common. In addition, aircraft operational availability is boosted through sustainment upgrades that increase component reliability and maintainability. Communications upgrades currently are expanding data link and satellite voice capabilities. Upgrades in weapons, countermeasures, radars, and targeting pods are also readily available and competitive.

Curtailed production of the F-22 increases the importance of upgrades in the F-22 fleet and for complementary platforms like the F-15C, F-15E, F-16, and F/A-18E/F. But two threats exist to market size and competition in upgrading U.S. 4th generation fighters. First, prioritization of F-35 funding and overall defense budget pressure combine to squeeze upgrade funding for other fighters. Second, lack of modularity and common interfaces, especially in Operational Flight Program (OFP) software, gives significant market advantage to the "owning" firms on a specific platform. Integrating news sensors or weapons in most cases requires changes to the aircraft's OFP, over which the primary firm has ownership. Competition in the upgrade market therefore primarily occurs in weapons and other stores, with the airframe prime performing overall integration even if it does not own the contract on the weapon or store.

Difficult budget-driven trade-off decision between F-35 procurement and legacy fighter upgrades recently resulted in cancellation of the Combat Avionics Program Extension Suite (CAPES) upgrade for 300 U.S. F-16s. Cancellation brought funding for F-16 upgrades down to $144M in 2014, compared to over $550M in equivalent dollars in 2006.[88] While the Air Force's 2015 budget submission did provide for a Service Life Extension Program (SLEP) to examine extension from 8000 to 12,000 hours, this appears to be a minimal effort to mitigate the operational impact of delays in the F-35's IOC date. Efforts are now underway to salvage portions of the CAPE program, including the AESA radar upgrade.

International upgrade market. Multiple trends are converging to increase competition in the international fighter upgrade market. The widely proliferated F-16 fleet is growing old and more nations can afford upgrades. Second, most 4th generation fighter lines are likely to cold within the next 5 years, including Europe's Eurofighter and Rafale, which to date has not been successfully exported. Fifth generation options are too expensive for many nations, leaving only the upgrade option for those lacking viable indigenous programs. For nations like Italy, Australia, and Canada, any funds spent on F-35 will squeeze Hornet upgrades

Indicative of the effect of globalization in linking domestic and foreign markets, cancellation of the U.S Air Force's CAPES program significantly affected Taiwan's F-16 upgrade plans. But concerns over China's rapidly growing military capability and the desire to strengthen security roles for U.S. strategic partners in the region resulted in saving F-16 radar upgrades for Taiwan's fleet of 146 aircraft.

The Asian F-16 upgrade market has emerged as the primary battleground between airframe OEMs and other companies seeking to win upgrade contracts. While Lockheed Martin had chosen Northrop Grumman to provide AESA radars for U.S. F-16s, Raytheon and BAE (as integrator) won the contract for over $1B in upgrades to 130 South Korean F-16s.[89] In an attempt to leverage this win, BAE is also seeking to provide training and logistical support and is pursuing fighter upgrade contracts in other nations including Singapore. [90] Boeing likewise has joined the fight for Singapore's F-16 upgrade program, indicating a widening wedge in OEM market share.

In summary, the international fighter upgrade market shows more promise of increased competition than the domestic one, but may not be large enough to support both Northrop and Raytheon as radar manufacturers. As domestic budgets tighten, U.S. firms increasingly seek foreign customers, but the international market is proving to be increasingly competitive.

Fighter Firm Strategies

Lockheed Martin strategy. Lockheed Martin Aeronautics is in the enviable position of producing, sustaining, and modernizing thousands of F-35s for the next several decades while also producing the venerable F-16—the most affordable export fighter among U.S. offerings. This enables Lockheed to provide tiered product offerings with F-35 at the top, a spectrum of F-16s in the middle, and F-16 upgrades at the low end for those customers who cannot afford new aircraft and seek to either improve their existing F-16s or modernize those acquired second-hand. Additionally, the effect of F-35 in eroding European competition strengthens Lockheed's market share globally. Consistent with this position, the company's probable fighter segment strategy objectives are to 1) execute the F-35 program, 2) gain new F-16 foreign sales—production continues through 2017 with current firm orders[91], and 3) compete and win F-16 upgrade contracts.[92] While Boeing and BAE are also competing for international F-16 upgrade contracts, Lockheed argues that maintaining commonality with the U.S. fleet is worthwhile, requiring Lockheed to perform the upgrades.[93] The firm will also seek to maximize its role in F-35 sustainment, which is likely to last several decades or more.

Primary threats to Lockheed Martin's F-35 program include technical risk, a postponed purchase decision by any customer (delaying unit cost efficiencies), and the potential for reduced or cancelled F-35C production. The F-35 program began with the U.S. Marine Corps's need to replace the Harrier and enjoys unwavering support from the Air Force—by far the program's largest customer. In contrast, the U.S. Navy began as a reluctant participant in JSF and might

bend to Boeing's growing campaign to trade a portion of the F-35C purchase for more EA-18G Growlers.[94]

Boeing strategy. Boeing is in a very difficult place in the fighter segment, facing the likely closure of both F-15 and F18 production lines within the next four years as international orders dry up and the F-35 consumes domestic demand. Given this position, Boeing's fighter strategy is to pull every lever it can to ensure continued F-18 production as a bridge to future programs (bomber, UCLASS[4], or 6th generation fighter).[95] This will likely include energizing its supplier base to lobby political representatives for additional domestic procurement, highlighting the relative merits of the EA-18G as a jamming platform in an anti-access environment, and seeking further foreign sales in Europe, the Middle East, and Canada."[96]

Relevant to this debate is the Navy's need to eventually replace its Super Hornets. This need will likely to be satisfied in one of three ways: 1) a Navy-specific program, 2) an improved F-35 variant, or 3) a joint 6th-generation fighter. But the Navy's Super Hornets will require recapitalization before the F-35 fleet grows old, enhancing the argument for a Navy-specific Hornet replacement. And if the F-35 program continues to grow in cost and schedule, this argument will gain even more strength as joint programs will look increasingly unappealing.

Northrop Grumman strategy. While Northrop Grumman has no fighter aircraft currently in operational use, the research team assessed that it is likely to participate in early conceptual studies for a 6th generation fighter. Further, we assess that Northrop's long-term prospect for a competitive position in the next fighter program depends on several factors, including the outcome of the LRS-B competition and design paradigms determined by user requirements. The greater the similarity of the next fighter to current fighters, the greater the disadvantage for Northrop Grumman. But if government R&D focus and performance requirements favor bomber, unmanned, or sensor-centric designs, Northrop may be able to create a design with enough credibility to generate the benefits of market competition. In either case, the firm's lack of recent experience in large-scale production and global supply chain management will be a marked disadvantage, further example of the negative consequences of fighter program infrequency and winner take all acquisition paradigm.

Fighters: Considerations for U.S. Government

Industry dynamics decades in the making cannot be solved overnight, nor are second and third order effects easily predicted. Now as always, the central need is for strategic decision making and clear communication of government priorities.

With no government intervention, it is likely that five years from now Boeing fighter production lines will be cold and thousands of engineers and skilled workers will be lost to other industries. Likewise, unless Lockheed earns sufficient F-16 export sales to keep its production

[4] Unmanned Carrier-Launched Airborne Surveillance and Strike

going at a trickle, the F-16 line will suffer the same fate. Further delays in the new bomber program will exacerbate the already difficult positions of Boeing and Northrop Grumman in the defense industry. If Northrop loses the bomber competition or the program slips too far, Boeing may attempt to acquire Northrop, leading to reduced competition in an even broader swath of defense services and products.

This future has strong negative implications for the U.S. defense industrial base and national security, as reduced competition will lead to higher prices for less-capable systems. Additionally, lost production capacity from divested and dispersed production hardware and human resources will further reduce our industrial remobilization capacity.[97]

Industry shaping. The U.S. government should shape toward a different future as follows. In the near term, maintain the F-18 line at minimum production by procuring additional aircraft and shaping foreign markets for near-term sales. In the medium term, maintain a minimum of three major military aircraft manufacturers by prioritizing industry health in the award of future contracts (bomber, UAVs). In the long-term, the government should re-establish staggered and service-specific aircraft procurement by replacing the Super Hornet with a wholly new design tailored to Navy requirements. Finally, the government should require itself to conduct an industrial impact assessment on any new program prior to Milestone B in an effort to avoid negative industry effects of the JSF industrial model.

Leverage blurring of platform categories. The rate at which future blurring of platform categories occurs will affect the ability of firms to enter or re-enter platform segments. Sensors and weapons employed on bombers, fighters, and UASs are increasingly similar and important relative to airframe performance, and aircraft complexity among differing platforms is converging. Atrophy of industry's ability to design fast and highly maneuverable aircraft is offset by reduced need in improving performance in these factors. Instead, future emphasis is likely in range, multispectral stealth, weapons advances, and system of systems platform integration--technologies that have cross-platform relevance. This blurring of platform categories could aid the resurrection of the industry phenomenon evident in the historical fighter periods summarized previously, in which firms in adjacent market segments were able to leverage firm-specific knowledge to re-enter and thrive in the fighter market.

As depicted in Figure 9, McDonnell Aircraft Corporation used experience gained in experimental jet prototypes to enter the fighter market during the dawn of jet propulsion. In a later period of revolutionary change, Lockheed and Northrop used their time away from fighters and bombers to develop stealth technologies, bearing fruit in their market re-entry with the B-2 and F-22. As platform lines are blurred, general and firm-specific capabilities can increasingly make up for atrophied system-specific knowledge. Boeing or Northrop could win a future fighter contract by developing revolutionary technologies (such as combat cloud enablers) while Lockheed is focusing on F-35 production and sustainment.

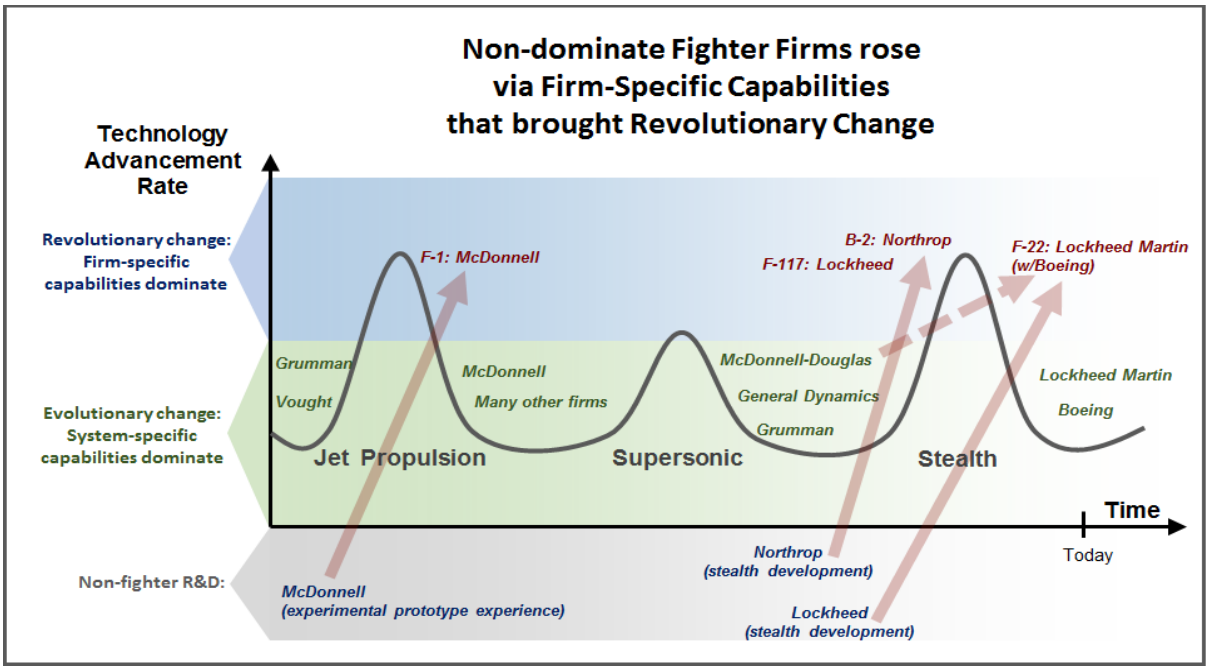


Figure 9. Examples of firm-specific knowledge enabling entry & rise of lesser firms[98]

Conclusion. In summary, the JSF acquisition model is the logical manifestation of increasingly extreme interactions between performance demands, complexity, cost, and development time. The impact on the U.S. fighter industry is fundamental, because while previous industry consolidation reduced the number of competitive firms from many to few, the transition currently under way is from few firms to one. Government decisions created this predicament, and government must lead the way back to industry health by defining and executing an industrial strategy which ensures true competition, innovation, and industrial capacity.

Unmanned Aircraft Systems (UAS)

The U.S. continues as global leader in advancing military unmanned aircraft systems (UAS) technology and operational science, especially in design of large complex air vehicles, weapons integration, global beyond line of sight operations, and operational integration with other platforms. The U.S. is projected to account for 51% of global procurement and 65% of global research and development spending on UAS technology during the next decade.[99] According to the 2014 Future Years Development plan, U.S. RDT&E funding will hold relatively constant for the next five years while procurement will rise in 2015 then hold constant through 2018.

UAS Suppliers and Market structure

The UAS industry differs from other aircraft industry segments in several ways. First it includes a much greater spectrum of system cost, complexity, size, and application. Second, the air vehicle itself is only one component of a UAS system, which can also include ground control stations and launch and recovery stations.

Predictions about the UAS industry are difficult to due market immaturity, preventing application of traditional market models based on historical trends. Additionally, the variety of business model options creates great diversity in firm expertise and interests, including air vehicle, ground station, data/comm links, cooperative flight algorithms, sensors, weapons, propulsion, and integrated power systems. Low barriers to entry enable market dynamics not common in other aircraft segments.[100] Lastly, fast design and production makes this segment attractive to students and young engineers who can begin with simple systems then grow into more complex and long-term programs. This advantage of the UAS industry poses a risk for developers of manned military aircraft, who must attract engineers and scientists without a guarantee of working on new programs.

The domestic UAS market is oligopolistic in all major air vehicle categories. Large/complex systems are currently produced by the major defense aircraft primes, while medium altitude long endurance (MALE) systems are dominated by General Atomics, with competition from Textron and AeroVironment. Small and micro UAS markets include a large diversity of firms due to low barriers to entry. The domestic UAS industry therefore has greater competition than the other aircraft segments, and the benefits of competition are likely to exist for the foreseeable future.

Foreign UAS markets and suppliers

Global R&D and procurement spending on unmanned systems is expected to double in the next 10 years. And as the counterinsurgency wars responsible for the explosive growth of the UAS industry fade, firms increasingly look to foreign markets to offset domestic budget pressure and shifting priorities. While attention is turning to Asia/Pacific, the most significant

foreign UAS market for U.S. firms is the Middle East, where export relationships in other aircraft and defense segments pave the way for transition from selling manned systems to unmanned systems. The UAE has emerged as the largest UAE operator in the Arab world, currently concentrating on the small end of the size spectrum but aggressive in building an indigenous design capability.[101]

Several factors likely will increase competition for U.S. firms in the Middle East. Israel has only 2% of the global UAS market share but is growing fast, has a proven record of UAS innovation and sophistication, and is not restricted by the Missile Technology Control Regime (MTCR), of which the U.S. is a signatory.[102] In 2013, the UAE ordered an unarmed version of the U.S. MQ-1 Predator after being refused sale of an armed version, in which Saudi Arabia was also interested.[103]

A second source of competition in the Middle East is Turkey. Limited by MTCR from buying U.S. unmanned systems, it is aggressively maturing its own UAS industry in order to meet $4B in domestic demand over the next 10 years,[104] and may seek foothold in the Middle East market. Its Anka MALE UAS has undergone significant flight test and deliveries are expected in 2016 with plans for eventual weaponization.[105] The long term success of U.S. firms in the Middle East is therefore not assured, and appetite for a weaponized UAS will only grow, complicating this market.

Europe has 4% of the global UAS market but faces a critical test of industrial unity. If European nations cannot coordinate a coherent UAS development effort, they are likely to suffer the inefficiencies and tensions of redundant and fragmented development, falling prey to the JSF model of dependence on the U.S. or relying significantly on Israeli exports.[106] An area in which Europe is more likely to demonstrate UAS innovation is airspace integration, motivated by lack of wide-open uninhabited areas enjoyed by the U.S.[107]

Meanwhile, China is prioritizing serious UAS development backed by rapidly rising defense spending and is not limited by international agreements nor laws. According to IHS Janes, the Chinese UAS development trajectory is steeper than that of any nation, and includes progress in developing stealthy weapons carrying platforms. Developments in Chinese capability therefore must be carefully observed.

Future issues and considerations for U.S. government

Shift from procurement to sustainment. As the first generations of widely-used MALE unmanned aircraft age and the industry matures as a whole, focus will begin shifting from system procurement to sustainment.[108] General Atomics' revenue will increasingly come from sustainment as production tapers for systems such as Predator, Reaper, and Grey Eagle.

Additionally, DoD is shifting UAS MRO capabilities from the defense primes to its organic depots in response to decreasing wartime funding and statutory requirements. In

November 2013, the DoD began a public private partnership between the Air Force and General Atomics to satisfy Title 10 "50/50" responsibilities. DoD initially fielded UAS capabilities to meet urgent operational needs by bypassing its traditional acquisition processes, with the intent to address long-term sustainment at a later date. UAS challenges in this context therefore include: 1) sustaining systems that were fielded as non-program of records, 2) lack of data rights, 3) transition from "contractor logistics support for life" to organic/depot capabilities, and 4) immature lifecycle sustainment planning due to rapid fielding.

MTCR and exports. As discussed above, MTCR restrictions will be an increasing barrier to profitable sales, especially in the Middle East. In the absence of a change in government policy, U.S. firms may elect to shift to a service model instead of sales transaction. Alternatively, the U.S. government may seek to change international rules, updating MTCR to reflect modern non-nuclear use of unmanned aircraft. Concern over proliferation is likely to play a central role in debate over changing rules. While high system cost and supporting infrastructure will likely prevent proliferation of long-range UASs, small and medium size systems will be increasingly in demand for both military and commercial use.[109] Potential uses by adversaries must be weighed against the benefits of relaxed exports laws.

Innovation and key technologies. As manned and unmanned platform lines continue to blur, the label "unmanned" is increasingly losing effectiveness as the central descriptor of this class of aircraft. From an industrial base design and production perspective, large complex unmanned aircraft have more in common with manned military aircraft than they do with the lower end of the UAS spectrum. It is therefore increasingly important to develop more relevant labels and categories for describing systems and technologies vital to future military air power.

Such categories include but are not limited to beyond line of sight communications, battlespace information sharing, cooperative flight, cooperative targeting, autonomous refueling, ground control, and self-healing networks. Each of these areas has relevance to both manned and unmanned flight. For example, manned aircraft already employ beyond line of sight communication, using the same systems as unmanned aircraft. Manned aircraft may one day be refueled autonomously, freeing the pilot(s) to rest or focus on other mission tasks. Likewise, manned aircraft may be employed in mixed formations with unmanned aircraft—all participating under autonomous or semi-autonomous flight control. Sensors on manned aircraft could be tasked by an operator in a ground control station, and cooperative weapons employment may involve both manned and unmanned aircraft with a flexible division of labor in target detection, transmission, and destruction.

A shift from thinking in terms of aircraft platforms and physical location of a pilot to thinking along key technology and capability lines is therefore a prerequisite to effective national industrial or technology development strategy. To this end we should not only ask whether U.S. industry is capable of producing air vehicles of a specific size and shape, but whether industry is incentivized and capable of innovation in the functional categories described above.

Mobility Aircraft

Air mobility (transport and aerial refueling) aircraft play a critical role in enabling American global military strategy and operations, from power projection, to air supremacy, counter-insurgency, major ground operations and humanitarian assistance/disaster relief. With near-term declines (followed by only gradual increases) in defense spending in the United States and Europe, and increased competition in other accessible markets, manufacturers of military mobility aircraft face a challenging marketplace and difficult strategic decisions.

Mobility Aircraft: Market Characteristics

For the purposes of this discussion, mobility aircraft include medium-to-large cargo and aerial refueling aircraft for both the U.S. and competitive export defense markets (excludes Russia and China). Foreign competitors will be considered as they relate to market competition and potential partners for U.S. prime and subcontractors. Specific aircraft discussed include those in current or projected production: the Boeing C-17 and KC-46, Lockheed Martin C-130 (and variants), Airbus A400M and A330 MRTT, and Embraer KC-390.

The market has several important characteristics that will likely affect major firm strategies during this downturn and beyond. First, the market is highly segmented—the aircraft, through their design and origin, rarely compete directly with one another. The C-17, C-130 and A400M each have notable differences in capacity and capability. The KC-46 and A330 MRTT briefly competed for the sole USAF contract, but do not directly compete on the global market. Even the KC-390, although comparable to the C-130 in size, boasts higher speed, but at the expense of likely higher operating costs. This lack of direct platform competition matters, as it speaks to the firms' (and backing national governments') demonstrated strategies of seeking market niches and greater autonomy, rather than competing on the grounds of better serving the same operational requirements.

Next, as the KC-390 shows, the direct involvement of governments (or multinational consortia) in backing the development, sales and creating predetermined markets for mobility aircraft, is highly significant. Further, the A400M was made possible by the explicit commitment from a multinational partnership to design and produce a fully new aircraft unlike any that had been designed or produced by any of the partner nations. The business case for the A400M as a stand-alone program was subordinated to the broader objectives to develop an indigenous European transport aircraft. This degree of government involvement illustrated not only the high priority many governments place on operational capabilities, but the even more important objective of developing their aircraft industrial base.

Third, few nations or firms will choose to enter the market without confirmed multi-national support, either in development/production or as committed buyers of the product. In the global, competitive marketplace, the United States stands virtually alone (excepting Russia) in its

capacity and commitment to unilaterally develop a major mobility aircraft. The A400, A330 MRTT and KC390 have been multinational efforts since conception—a critical difference in business philosophy.

A fourth notable characteristic of the mobility aircraft market is the relatively little uncertainly—to the up or down-side—regarding the market opportunities for the major aircraft competing in the market. The C-17, dominant in its segment (of one), will go out of production by next year. The KC-46 is unlikely to find any major buyers beyond the USAF. Nor is the USAF likely to significantly cut the KC-46 buy, as aerial refueling is a critical factor in U.S. operational concepts and global operations and the KC-135 airframes must soon begin retirement. While Airbus and Embraer will certainly welcome additional buyers of the A400M, MRTT and KC-390, few additional buyers are likely (of the three aircraft, only the future marketability of the KC-390 remains a real unknown). The C-130, due to its versatility, proven reliability, relative affordability and global market reach, represents the platform still with potentially the most to gain in future sales (over 70 nations have operated the C-130).

These factors together influence how the major mobility aircraft firms (and their national governments) prioritize mobility aircraft businesses with broader firm strategies, and how they balance between production execution (time, cost and performance), market expansion, asset reallocation, research, and development.

Mobility Aircraft: Firm Strategy Analysis

Boeing: Boeing's two major mobility aircraft programs have little in common and this is reflected in how they will fare in the near future. The C-17 program came to Boeing with its take-over of McDonnell-Douglas, and with the last aircraft due to roll out in mid-2015, Boeing has conceded that the Long Beach plant will close. The KC-46 tanker-transport, a derivative of the 767, has a secure future as the replacement for the Boeing KC-135 tanker. Unlike earlier post-production modified KC-767s, the KC-46 has been specifically engineered for aerial refueling and military cargo transport, and faces no further competition for the USAF mission. However, its viability in the limited international aerial refueling aircraft market thus far appears limited, as it faces competition from the Airbus A330 MRTT and the (less capable) KC-130 (post-production modified C-130).

In short, given Boeing's overall firm structure and the certain futures of both the C-17 and KC-46, there is little to deter Boeing from staying course. Boeing will close the C-17 line on schedule and maintain the KC-46 production rate, per its existing contract. Boeing will continue to market the KC-46 to potential export customers, however, those remain limited in number and overall demand. Looking forward, the more interesting decision for Boeing is how best to compete for a possible KC-10 replacement.

Lockheed Martin. With a different allocation of businesses within the firm structure, Lockheed is far more reliant on the success of the venerable C-130 line of aircraft. Unlike

Boeing, Lockheed is primarily a defense supplier, with no steady, major source of commercial revenue. However, while Lockheed is rightly focused on timely and cost-controlled execution of the F-35 program, it relies on the C-130 program for reliable revenue. The near-term looks bright in this regard, with C-130 production steadily meeting global market demands at a rate of 24 aircraft per year. With a maximum line capacity of 36 aircraft per year, Lockheed has some room to grow should domestic or international demand increase. Toward that end, Lockheed will continue to aggressively market the C-130 as not only a cargo aircraft, but a flexible, multi-mission airframe tailorable for commercial cargo (known as the L-100), aerial refueling, and surveillance missions.

In seeking to expand the global appeal of the C-130, Lockheed faces two notable challenges. First, the target customer base is comprised of diverse and generally smaller individual defense importers (such as smaller European and Asia-Pacific nations), with varying acquisition processes and offset requirements, not to mention host nation-sponsored rival aircraft. Second, seemingly slow in coming to terms with the diverse and more competitive global defense marketplace, Lockheed has only recently articulated a strategy to synchronize and coordinate its global export operations. Although belated, the strategy reflects an internal recognition that, in this period of defense acquisition downturn, the firm must more effectively leverage its diverse product offerings rather than relying on major and enduring programs such as the F-16 and C-130.

Airbus. With the A400M and A330 MRTT, Airbus offers two aircraft facing quite different market conditions. The A400M fills a niche between the C-130 and C-17, with few (if any) prospective buyers truly cross-shopping among Airbus, Lockheed and Boeing products. The A400M, despite its many programmatic difficulties, has finally entered the market with no significant direct competition, allowing Airbus to continue marketing the aircraft on its own merits, such as they are. The A330 MRTT theoretically faces more direct competition from the slightly smaller Boeing KC-46. However, the market for either aircraft, outside of the U.S. or countries of the Airbus consortium, is extremely limited. The prospect of significant sales of the MRTT is remote, but shortfalls are not likely to impact other Airbus operations (other than the bottom line).

Given the well-bounded fates of the A400 and MRTT, Airbus is likely to focus on efficient execution of the A400M contracts, while positioning the MRTT (or perhaps a later A350 derivative) for competition for the potential KC-Y replacement for the KC-10. Like Boeing, Airbus will increase its focus on its commercial aircraft operations, as the military mobility aircraft programs mature and phase out, but appears to have no deeper strategy for dealing with this transition.

Embraer. Like Boeing and Airbus, Embraer is and will remain primarily a commercial aircraft producer. However, the development of the KC-390 reveals three interesting aspects of Embraer's systems selection and integration process. First, Embraer worked closely with

American firms such as Rockwell-Collins, Pratt & Whitney and Goodrich, to ease U.S. concerns over an emergent threat to the C-130 aircraft. Second, the KC-390 incorporates many commercial components to control costs and reduce technology risk. Third, the use of such commercial components reduces the risk of interruption from the International Trafficking in Arms Regulations (ITAR) in a manner similar to Brazil's purchase of the Swedish SAAB Gripen fighter (that is, replacing restricted U.S. components with those from other sources). Embraer has also teamed with Boeing, who will "lead sales, marketing, training and sustainment of the KC-390 in the United States, United Kingdom and two unmanned Middle East countries."

The KC-390 project is also representative of a broader effort by the government of Brazil to exploit Brazil's relative technological-industrial strengths in Latin America, exploit bilateral international military-industrial relationships, and broaden Brazil's defense-industrial capabilities through targeted partnerships in the KC-390 program. First, Brazil stands alone in Latin America with a relatively broad and deep industrial capability. As Jane's notes, "Only Brazil stands as a credible world market competitor – notably in aerospace domains. Other South American states are more likely to achieve export advancement through offset-derived export facilitation in near to medium term."[110] Brazil has established several defense-industrial relationships with global "near-peers" both to expand its capabilities and grow potential export markets. However, there are still gaps in Brazil's defense-industrial capabilities, notably in naval, space and C4I design. Brazil's teaming with Argentina and Chile potentially brings access to their experience in radar and remote sensing systems, respectively.

Finally, while Boeing's involvement in the KC-390 project may well be a win-win for Boeing and Embraer, Boeing's failure to gain selection for Brazil's new fighter program was a set-back to what may have been a greater expansion of Boeing's MRO business in Brazil and Latin America. Regardless, Boeing's stake in the KC-390 is a moderate hedge against termination of C-17 production and Lockheed's historical dominance in the tactical airlift market.

Mobility Aircraft: Implications for the U.S. Government

Current Force Structure. Focusing on first principles, U.S. defense industry must maintain the capability and capacity to meet current and anticipated U.S. warfighting requirements. While this discussion does not examine in great detail all U.S. threats, missions, and operational constructs that drive force capability and capacity requirements, it is clear that U.S. national and defense strategies demand the capability to mobilize and sustain major ground, air and expeditionary forces globally and for potentially years at a time; air mobility forces are critical in this regard. The Asia-Pacific rebalancing certainly maintains this requirement, although the baseline U.S. air mobility force that supported the wars in Iraq and Afghanistan is projected to be adequate for baseline warfighting assumptions.

Contingency Surge. Next, however, is the potential requirement to surge production and deployment to meet enduring, long-range contingency operations, to include the replacement of

combat losses. The latter scenario is one that has gone largely unaddressed, as U.S. military operations (post-World War II) have placed mobility aircraft where they generally are not held at risk by hostile forces. Major combat operations in the Asia-Pacific region may force reexamination of this assumption, resulting in potentially larger air mobility forces and surge production of C-130 and C-17 aircraft, for example. There is, of course, a complex trade-space among aircraft force structure and posture, operational constructs, basing options, and defensive capabilities (both operational and tactical). Regardless, surge capacity must be addressed in subsequent studies. Likewise, exogenous scenarios may stress the capabilities of existing mobility assets in situations such as major ground operations deep in the Eurasian landmass, or the ability to move forces through nuclear contaminated environments.

Research and Development / Innovation. A strong defense industrial base can enable—with effective incentives—robust investment toward the next generation of mobility aircraft (as well as wholly alternate means of transport). Trends in rising fuel costs, changing operational constructs that stress flexible mobility, and evolving threats demand research into more fuel-efficient, long-range, survivable, or even unmanned air mobility options. There is trade-space among mobility aircraft options, alternate means of transport, capabilities/capacities of supported combat systems (air, ground and naval), and operational concepts, but R&D—often independent corporate R&D—not only helps hedge against changing threats and requirements, but opens the aperture of conceivable operational and logistic strategies to deal with contingency or exogenous scenarios mentioned previously.

Foreign Sales. Exporting U.S. mobility aircraft (and related support) serves various security interests. Extending production runs for increased profits and reduced costs, increasing the capabilities of allies for security burden sharing, enabling interoperability with U.S. forces and logistics constructs, and fostering common operational and strategic relationships all increase U.S. national security. Perhaps more pointedly, continuing a materiel relationship as the primary supplier of mobility aircraft maintains a degree of dependency (and motivation for geo-political cooperation) within those customer states. Other exporters of similar aircraft have similar interests, although (as has been discussed) the government-industrial structural relations in the cases of Airbus and Embraer affect how they look at the marketplace and their own imperatives in defense aircraft production and export.

As both the major customer and the primary regulator for defense industry, the government must be attuned to industry's strategic view and concerns. A late 2012 survey of defense industry executives revealed that, in the context of the near-term defense budgetary downturn, what they sought most from government was "transparency, simplification and acceleration of processes…more open dialogue and collaboration…and a clearly strategy backed by a long-term plan…for increasing consistency."[111] Budget stability and multi-year contracts can provide industry more reliable planning criteria and revenue streams to support execution of current contracts and targeted investments in research and development. Working closely with industry to develop viable and imaginative operational constructs that leverage America's

strategic advantages in mobility infrastructure and defense industrial base can similarly provide industry more time and clarity to develop and deliver the proper force mix. Maintenance of a viable and competitive U.S. military aircraft industrial base is a vital component in preparing not just for known future requirements, but for strategic surprises in a dynamic global environment.

Large Commercial Aircraft (LCA)

The Large Commercial Aircraft (LCA) industry operates primarily in commercial markets, with military derivative aircraft and associated technologies forming the primary link to defense markets. The commercial foundation for both Boeing and Airbus provides the firms with increased freedom to innovate without direct governmental oversight, but with the ability to leverage developments in both commercial and military product lines as conditions warrant. The Airbus and Boeing duopoly has grown and changed in the past 10 years, and differences have emerged in how they approach their business strategies, competition, and major trends in the sustainment, supply chain and maintenance repair and overhaul (MRO) markets.

LCA: Market Characteristics

The LCA market can be defined to include single-aisle (narrow-body) and twin-aisle (widebody) passenger and cargo aircraft.[112] Specifically, this analysis focuses on the Boeing 737, 747, 757, 767, 777, and 787 product lines plus variants, and the Airbus A320, A330, A350, and A380 product lines plus variants. There are no other firms currently producing LCA with market share worth mentioning, and smaller regional jets are not considered here. There are a few international firms/nationalized industries which have been investing in either regaining an LCA capability (Russia) or establishing a domestic capability (China).[113] One potentially significant entrant into the LCA market is COMAC, the Chinese national firm. However, as a RAND study concludes, in the near term, COMAC will not execute a commercially viable design in the near term, with a future path likely derived from a follow on design to the C919.[114] Figure 10 is provided by an industry consultant and further reveals the duopolistic reality of the LCA market continuing out past 2023.[115]

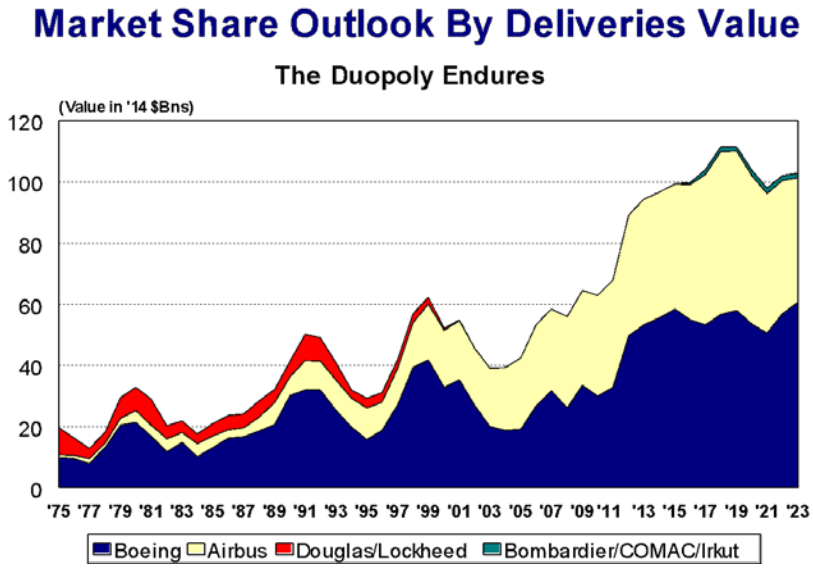


Figure 10. Airbus, Boeing duopoly continues[116]

Boeing and Airbus are organized in a similar fashion with one main business managing commercial aircraft and another the military aircraft market. In 2013, Boeing Commercial Aircraft (BCA) accounted for 60% of total firm revenue[117] and Airbus civilian sector accounted for almost 80% of Airbus Group revenue in 2013.[118] While both companies are publically traded firms, Airbus has minority shares controlled by European countries (France, Germany, Spain, UK).[119]

Boeing and Airbus compete at various aircraft sizes, defined by seat capacity. The major competition for customers is in the narrow body 150-190 passenger class, projected to comprise up to 70% of new deliveries for Boeing through 2032.[120] Airbus has essentially an identical forecast with regard to number of airframes in the narrow body class.[121] Each firm also offers capabilities in the wide body class with Airbus viewing the future market comprising a 59% share of the total market value (through 2032),[122] while Boeing projects it to comprise 45% of the market.[123] This disparity in forecasting value explains the firms' slightly different strategies.

In addition to the wide range of LCA airframes, each firm offers commercial derivative aircraft for sale to militaries on the international market. Boeing offers two, the KC-46 tanker derived from the 767 line, and the P-8 maritime patrol aircraft derived from the 737 line. According to industry executives, these derivatives are primarily BCA products, then sold to BDS for military specific customization prior to delivery to the customer.[124] This relationship benefits Boeing's defense and commercial aircraft divisions, plus the DoD, by leveraging previous research and development and focusing on the limited areas where additional investment is warranted. This is particularly relevant in a defense spending downturn as reduced resources are required on the front end of the procurement.

Airbus leveraged the A330 line to derive the Multi Role Tanker Transport (MRTT) and is offering this on the international market to those countries desiring a versatile aircraft which can be configured for various missions. To date, Airbus has sold and begun to deliver MRTT to four countries (UK, UAE, Saudi Arabia, and Australia). In addition to these firm orders, several more nations have recently either expressed an MRTT preference or signed tenders to procure the MRTT. They include Singapore[125], India[126], France[127], and Qatar[128]. Airbus has taken a substantial lead in the international tanker, transport market and it is unclear in the near term whether Boeing can compete or even enter the market.

Within the past ten to fifteen years both Boeing and Airbus have each developed and begun to deliver a near clean sheet design. This limits the appetite for a near term round of new designs. Boeing recently finished the 787 design and has continued to ramp up the production line to deliver the first newly designed aircraft. With an estimated $15B development investment required for the 787, Boeing is unlikely to invest in a new design in the near term and will instead focus on pressuring the supply chain to innovate and drive cost down. [129]

Improvements to current airframes will continue to focus on the fuel efficiency and increasing range through advancements in composite structures, engine technology and

aerodynamic optimizations. Additional innovations, from an airliner perspective, will be in the passenger cabin and focused on providing a marginally improved experience to differentiate among competing airliners.

A critically important innovation/change in philosophy is the Boeing-supplier relationship. Boeing's Partnership for Success (PFS) program has resulted in Boeing pushing design responsibility and attempted cost savings down the supply chain. One consequence of this has been a consolidation of suppliers. While savings have been realized, the consolidation has also created more sole source suppliers and increased the supplier dependence of Boeing. It remains to be seen how this will affect the leverage Boeing has historically held over suppliers. Industry observers are skeptical that the suppliers will continue to produce savings for Boeing. [130]

While this concept was initiated for the 787 airframe (and had well documented difficulties and missteps), it has expanded to other Boeing production lines. In addition to creating supplier PFS relationships, Boeing penalizes those suppliers that are either unwilling or unable to sign up to this cost saving initiative. Boeing has even created a 'no-fly list' of those suppliers which do not sign on to the PFS model. For military aircraft from commercial derivatives, this could introduce new supply chain risks that haven't been fully appreciated to date.

MRO of commercial aircraft is a large global market ($56.8B in 2012, and expected to grow to $85B in 2022[131]) and will continue to be a critical aspect of the industry. As with the general LCA market, the global commercial MRO market growth is concentrated in the Asia-Pacific and the Middle East.[132] Given the large revenue available, the LCA firms established global networks to capture this work and could be leveraged by military customers of commercial derivative airframes. Commercial best practices such as inventory reduction and just-in-time concepts are also appropriate in certain military environments and have been incorporated on the DoD side. But military unique requirements (e.g. 50/50 rules and organic repair requirements) that don't accommodate commercial best practices may limit opportunities for leveraging such cost savings and delivery efficiencies.

LCA: Firm Strategies

Both Airbus and Boeing have invested in the Asian-Pacific region and view it as the major growth market globally both near and far term. Beyond the Asia-Pacific, emerging markets in Latin America and the Middle East will increase market share in the long term. Due to the long term relationship between airlines and manufacturers established via aircraft sale, the near term is critical to how each firm is positioned in 2032. Sales between now and 2017 will help inform the firms as to whether they will be able to reach their sales forecasts. While both firms are invested in very large airframes (747, A380), the majority of the competition will occur between the 737 and the A320. By 2032 Airbus forecasts over 20,000 new deliveries of single

aisle planes[133] and Boeing projects over 24,000 new deliveries.[134] The other airframes combined make up less than half of the remaining new airframe deliveries.

From a commercial derivative perspective, Airbus and Boeing are also competing with the MRTT and the KC-46, respectively, in the tanker market. In addition, although the KC-390 is primarily a medium cargo aircraft designed to compete with the Lockheed Martin C-130J and the Airbus A400M, Embraer is marketing it as tanker configurable.[135] For further analysis, see the mobility aircraft section of this report. In general, both firms seem unlikely to generate significant future sales of their tanker platforms, and both are in a wait and see mode regarding the timing of the next U.S. tanker competition. For additional relevant analysis of other derivative, special purpose aircraft (e.g. maritime patrol), see the relevant section in this report.

LCA: Implications for the U.S. Government

Broadly speaking, the intense competition between Boeing and Airbus in the LCA market is good for the airline passenger and freight customer. In the near term, both firms in the duopoly are profitable and healthy financially and there is little the government needs to change in its approach.

For Boeing commercial derivative aircraft, there are four implications for the U.S. Government: intellectual property, international sales, the survival of BDS, and future requirements risk in an anti-access area denial (A2AD) environment.

With regard to intellectual property for commercially based designs, the government needs to consider liberal approaches for acquiring data rights for commercially based designs. Specifically, DoD has the opportunity to leverage the established 737 and 767 global supply chain and MRO infrastructure developed by Boeing. One industry consultant defined the P-8 work share between BCA and BDS as 60/40[136], and Boeing claimed at a 2012 Aviation Week MRO conference that the KC-46 contains 85% commercially common parts and only 15% KC-46 unique parts.[137] A DoD concurrent supply chain and/or MRO infrastructure to maintain the commercially common parts and repairs creates waste and complexity that is likely not required, particularly in this fiscal environment. While the P-8 program plans to leverage the 737 commercial global MRO and spares network, [138] it appears the Air Force may be pursuing a wholly organic approach to the KC-46.[139]

With respect to international sales, limited foreign nation defense budgets do not support relatively expensive, dedicated tanker aircraft such as the KC-46. In any tanker competition, without the weight of the U.S. government to assist in the sale of the system, Boeing will likely struggle to penetrate sufficient international markets to make foreign sales more than a negligible aspect of the program. Without this international market, the 767 production line may close at the completion of the KC-46 program. The current program of record calls for the final aircraft to be delivered by 2027.[140] There are two additional follow-on programs, KC-Y and KC-Z which could extend the line, but these competitions are not anticipated to begin for some time and it

seems apparent that Airbus intends to compete. One thing is clear: if the U.S. wishes to continue to have air refueling capability, procurement of replacement aircraft will be required as the current fleet will be reaching the end of its useful life. This follow-on decision is outside the scope and timeline for this paper, but it does offer an option to keep a commercial derivative line open for the next 20 plus years.

In light of the likely end to F-18 and F-16 production, along with the final delivery of the C-17, it appears that BDS, and specifically Boeing Military Aircraft (BMA), is increasingly at risk as a viable business. The KC-46 commercial derivative will only partially sustain BMA over the near and mid-term. But keeping its military aircraft business competitive may require Boeing corporate headquarters to subsidize BDS activities with BCA profits as a near term bridge to future programs. However, BMA would have to develop an executable and winnable strategy or business case to win new programs. The long range strike bomber or a lower end, international fighter aircraft are two such possible paths. Short of purposely awarding new development work to Boeing, there does not seem to be much action for DoD to take, as the current situation is a direct outcome of a series of past decisions and the current budget limitations. Perhaps direct communication on future requirements with realistic planned timelines is the best DoD has to offer by way of firming up the decision space for Boeing.

The final discussion point centers on the risk to commercial derivative aircraft in and around an A2AD environment. Apart from issues of survivability, how would a peacetime, international, hybrid supply chain and MRO agreement between the DoD and Boeing for the P-8 and KC-46 support the military in a protracted, high intensity environment? International suppliers might decide to stop supporting Boeing or be unable to obtain raw material required to manufacture parts. If the DoD moves forward with a hybrid contractor/organic MRO strategy as seems likely at least in the short term for both KC-46 and the P-8 (longer for the P-8), there is a risk that in a high intensity environment, the commercial piece of sustainment will be shut down or at least not be as effective as required by the DoD. Even without a hybrid MRO/supply chain strategy there is a question as to how these commercially designed airframes will perform in a high intensity, contested environment like the A2AD scenario, and requirements for such systems do not seem forthcoming even in light of stated strategic shifts to the Asia-Pacific theater.

Special Mission Aircraft, Commercial Derivatives, and LRS-B

The need for airborne surveillance has never been greater. In the context of the current defense downturn, countries selecting platforms for next-generation manned aircraft with ISR-related capabilities are at a particularly interesting crossroads. The market is made up of options ranging from 50,000 pound business jet class derivatives such as Boeing's new MSA aircraft (a version of a Bombardier Challenger 605), to a fully loaded 130,000 pound P-8 Poseidon. Venerable planes such as the P-3 Orion, E-8 JSTARS and various models of the Atlantique, continue to operate worldwide. Additionally, the next generation bomber, or Long Range Strike Bomber (LRS-B) is on the horizon for the U.S., and while analysis here will be brief due to program classification, this program may impact the U.S. industrial base and the future of large, domestic primes.

Special Mission Aircraft: Market Structure

Domestically, Boeing is at the center of the special mission market. Given the successful Initial Operation Capability (IOC) of the P-8 Poseidon with the U.S. Navy, Boeing has successfully introduced a brand new platform into the global market—one that has certainly changed the balance of power in the industry. Additionally, Boeing is achieving success in direct commercial sales of derivatives with their E-7A "Wedgetail", a militarized B-737 that is being operated by countries such as Australia and Turkey. However, the P-3 continues to be operated by many countries worldwide. With Lockheed and L-3 Communications providing long-term sustainment and overhaul, the P-3 will be a central ISR platform until mid-century. Lastly, the Breguet 1150 Atlantique (now commonly known as the ATL2) continues to operate in strong numbers as well, as France has recently signed with Dassault and Thales to overhaul 15 aircraft for service into the 2030's.

In assessing the global outlook for this market, it is important to note that many other traditional military powers have faced the same budget challenges in recent years that the U.S. has experienced. Without the U.S. as launch customer, it is significantly more difficult for U.S. aircraft manufacturers to launch a system that does not directly involve the U.S. military. This has forced traditional maritime powers such as France and the United Kingdom to agree to partnering and collaboration on a wide range of military systems that they used to procure and field on their own. In Asia/Pacific, traditional military and maritime powers allied with the U.S. are hesitant to buy expensive aircraft, and with the F-35 JSF program creating significant budget pressure for many of the U.S. allies (such as Japan, South Korea and Australia) buying additional expensive U.S. systems could prove challenging.

A key feature of the market is the use of commercial derivative aircraft. Boeing has been very successful at producing a vast number of both their B-737 (ISR) and B-767 (tanker and mobility) derivatives. Lockheed Martin is clearly marketing the C-130J Hercules as an uber-

flexible platform, capable of carrying "roll-on / roll-off" systems that can easily perform virtually every kind of surveillance and reconnaissance mission, over land or over water.

Another key market trend is best described as "downsizing". As mentioned before, traditional powers (UK and France) are being forced to make increasingly difficult decisions due to shrinking military budgets—a significant trend that could lead to these countries abdicating traditional missions altogether. The UK, for example, will have to decide in the near term if it will continue to conduct maritime patrol operations. With few choices on the market and their Nimrod fleet now inactive, the decision point on what (if any) replacement aircraft to buy is at hand, and the approaching decision remains unclear, adding to the "bottom-line" pressures for Boeing and Lockheed Martin.

Innovation occurs in this market, but is evolutionary and not revolutionary. Three trends are evident: emphasis on Net Centric Warfare (NCW), new aircraft engine efficiencies, and innovative next-generation supply chain techniques. For example, the P-8 was bought and sold using a "family of systems" approach with other various manned and unmanned platforms; the NCW infrastructure was taken into consideration as the aircraft was built and the U.S. Navy designed it to be plug and play at IOC. Another advantage the P-8 has is the implementation of ultra-efficient engines that share commonality with the world-wide B-737 community, which enables P-8 customers to benefit from innovation in the 737. Lastly, Boeing and the U.S. Navy are able to support the P-8 with a tested and iterative supply chain that has been proven over the better part of the last 40 years. Supply chain metrics have been written into the contract and it appears at the outset of the P-8's operational life, it could not have a more robust supply chain than what is currently in place.

While not the focus of this discussion, it is important to briefly discuss the impact of unmanned systems on this market. Considering the family of systems approach that is currently en vogue, any new manned aircraft (especially a large purpose built surveillance aircraft) is designed, built and purchased with unmanned systems integration in mind. For example, it is clear that some version of the P-8 will have critical links to various U.S. Navy and U.S. Air Force unmanned platforms. The same can be said for the Australian P-8's, and a country like the UK would approach the purchase with the same dynamic in mind. The question will be: how much impact will the procurement of unmanned systems have on large ISR-centric manned aircraft? It is likely that the answer to this question will only become clear during sustained combat operations and could yet be 10 years away before the Pentagon truly recognizes and reacts to the various impacts of unmanned aircraft in large numbers.

Special Mission Aircraft: Firm Strategies

Apart from existing domestic orders, Boeing's goals for international sales are high and possibly optimistic, with estimates of anywhere from 60-75 units desired to be sold. Australia's P-8 purchase was critical for Boeing. It can be argued that Australia seeks a "special relationship" with the United States, much as the UK had with the U.S. in the wars of the middle

and later part of the 20th century. Australia is crucial to any coherent military and diplomatic strategy in the Asia Pacific, and with the U.S. as a "launch customer" for platforms such as the F-35, it was straightforward for Boeing to copy the model with the P-8 and the follow-on family of systems. With the U.S., Australia and India all operating the P-8, Boeing will leverage their well-established logistics networks and hubs and will be well positioned to support MRO for the P-8 in the region for decades to come. And – even though the Royal Australian Air Force has elected to operate the KC-30A Multi Role Tanker Transport (MRTT), a modified Airbus A330, they have ensured interoperability with F-35, F-18 and P-8, thus providing a "significant contribution to U.S. operations within the strategic quadrangle as well."[141]

Another important potential customer in the Asia Pacific is Japan. While Japan has experienced difficulties with its indigenously produced P-1 aircraft, the door may open in the near future to a switch to the P-8 if the situation isn't resolved in time for planned retirements of Japan's P-3 fleet. Future sales opportunities in Singapore and Indonesia are also a natural consideration.

The Asia Pacific region is certainly elemental to Boeing's strategy in this market, but it doesn't tell the whole story. Possible sales to the UK, or to the U.S. Air Force as a replacement for Boeing 707-based JSTARS aircraft, round out other potential future customers. Boeing contends the P-8 "AGS" "offers a more capable, cost-effective alternative to modernizing the 17 modified, 40 year old 707-300 JSTARS aircraft…".[142] With forecasted operating costs potentially 60 percent lower and potential annual savings at approximately $500 million a year, Boeing makes a "tremendous and compelling case for the aircraft", says Bob Feldman of Boeing.[143]

In addition to the P-8, Boeing has continued aggressive progress on the smaller "MSA" aircraft, a business jet with downsized P-8 capabilities, for the customer who doesn't want (or can't afford) the overhead of the P-8. Boeing has teamed with Field Aviation to produce a competitive platform that will compete with aircraft such as the SAAB 340 and the Dassault Falcon 900/2000 for a share of what Boeing estimates as a $10 billion market. As Robert Schoeffling of Boeing alluded to in an Aviation Week interview, the Boeing MSA will set itself apart with open-mission software from the P-8, which will manage a variety of sensor options that include a 360 degree AESA radar. As BDS faces the probability of the F-18 and F-15 production lines going cold in the very near term, they face no choice but to aggressively exploit every facet of the ISR medium and large aircraft market.

Lockheed Martin's current strategy centers on the C-130J Hercules. A proven and robust platform, there are dozens of customers and numerous versions of the aircraft operating all over the globe today. Lockheed has "iterated" the J model in effective ways, and is now marketing a "SEA HERC" option. Depending on the option(s) a customer chooses, one could perform missions ranging from basic coastal surveillance to armed anti-submarine warfare. Some analysts suggest that while this option may very well be capable and enticing, it is at least 12-24

months from becoming a platform that a customer could actually touch and fly. More to the point, without the U.S. as a "launch customer" there is little chance that Lockheed has a realistic opportunity to produce these aircraft in any significant numbers and the capital investment required would not provide a worthwhile return on investment.

But not all is lost in this category for Lockheed Martin. There are upwards of 10-15 countries – including the U.S. – that still operate the P-3. Thus, there is still a significant market for Lockheed in the P-3 sustainment/re-winging/MRO business. A prime example of this dynamic is Norway, which moved aggressively in 2007 to build multiple kits for six of their aging P-3's, so that the platform could continue to perform for an additional 20-25 years. However, Lockheed and L-3 Communications will need to work closely with the U.S. Navy, as L-3 cut its payrolls in January 2014 due to the U.S. Navy's decision to submit fewer P-3's for sustainment than had been planned.

Airbus had contemplated fielding an MPA derivative from their existing A319/A320 line, but ultimately made the decision to not field the aircraft. There is little publicly available information that provides insight into this decision, but Airbus seems to have conceded this segment of the market. It seems that fielding any MPA derivative is simply not in Airbus's long-term strategy.

Long Range Strike Bomber

A brief discussion about the U.S.'s next bomber, dubbed the Long Range Strike Bomber (LRS-B), is necessary in the context of this paper. Envisioned as a program of 80-100 aircraft, the main firms that are competing are Northrop Grumman (NG) and a partnership between Boeing (primary) and Lockheed Martin. NG is clearly positioning itself as the sole experienced producer of stealth bomber aircraft.

However, critics of this program are not only questioning size, scope and price of this program (warranted criticism for a Pentagon that simply has been unable to control cost and schedule in the F-35 program), but are also questioning the necessity of the platform to begin with. Perhaps most disconcerting, if certain technological shifts make the platform more observable, the U.S. could end up spending $800 million to $1 billion per aircraft to perform a mission that could be performed by legacy platforms. Additionally, this program begs the question about the current construct of the nuclear triad and what, if any, evolution should the construct of the triad undergo?

Mark Gunzinger, a former Deputy Assistant Secretary of Defense for Forces Transformation and Resources and adviser on the 2010 Quadrennial Defense Review (QDR), believes a new bomber is a fundamental pillar to any future U.S. defense posture and that the current fleet is quickly becoming outdated vis-à-vis a contested airspace conflict. However, the current budgetary battles loom large. "While a new penetrating bomber will require all-aspect, broadband stealth and other self-protection measures, its weight and payload capacity cannot

result in an average unit cost that is so great that it would effectively limit the Air Force to procuring a small "silver bullet" force on the order of today's twenty-aircraft B-2 fleet," writes Gunzinger.[144] As previously stated, not only has the JSF model affected all future aircraft acquisition programs, but the execution has as well. That said, Gunzinger obviously is expressing concern that many inside the Pentagon and on the Hill currently have – can DoD deliver an aircraft program of this magnitude, on schedule and equally important, on budget.

That concern transitions well into a recommended strategy for the USG, and one the Pentagon has been increasingly using effectively – the previously mentioned "family of systems" approach. In the case of LRS-B, one can argue that a "system of systems" approach may be more accurate. Regardless of the terminology, it is a concept that Gunzinger and former Air Force Lt. Gen. Dave Deptula recognize as a powerful argument, as they authored a report concentrating on a "reconnaissance strike complex", which integrates bombers, drones, ships and submarines, and certainly accentuates the joint element to a future long range strike battle-space.[145] An additional political element to this program is the aforementioned question of what a future nuclear triad looks like. From an acquisition perspective, the Air Force and the Pentagon are on the right path in that they are essentially putting off that debate and concentrating on the conventional requirements for the LRSB. In that context, they have packaged the program as possessing obvious and elemental nuclear capabilities when the need arises; this should position DoD well with respect to LRSB's link to the nuclear triad if, and only if, they are able to stick to schedule and budget. Not a foregone conclusion as we have seen in the JSF program.

The last consideration about LRS-B is the impact of the current JSF acquisition model on the industrial base. In light of the "winner take all" environment that JSF has helped to create, the selection of the winner in the LRS-B program will have long lasting effects, if the aircraft is ever produced in significant numbers. With Lockheed and Boeing partnering, it is clear that both firms seek to cement their competitive advantages in the aerospace market, and if they are awarded the contract, may well force Northrop Grumman out of the aircraft design business. LRS-B is central to any strategy that NG has to stay relevant in the combat aircraft industry and will rightly argue to the Pentagon that if it has any interest in maintaining a diverse and robust industrial base, it will look to NG to build the LRS-B.

Special Mission Aircraft: Implications for the U.S. Government

Boeing Defense and Space (BDS) is at a critical juncture in their military aircraft business. As is widely reported, their F-18 and F-15 lines are likely to shutter in the near term. That said, BDS has been aggressive with respect to the P-8 program, using partnerships to field a smaller MSA aircraft, and is wisely leveraging various derivatives of its successful and dependable 737 business. Boeing is correctly incorporating a family of systems strategy, and is trying to influence the USAF to use the P-8 platform for its JSTARS replacement aircraft. Additionally, the KC-46 program will remain under intense scrutiny, so the pressure to deliver

on-time and on-budget is high, and Boeing is using recent lessons learned from the P-8 program to ensure the tanker is delivered by its intended IOC date. However, FMS sales for P-8 have been weak and the loss of the fighter line in St. Louis will put BDS under significant pressure in the next 3-5 years. If the Boeing / LM partnership does not win the LRS-B contract, BDS will continue to depend on the liquidity of Boeing commercial aircraft to insulate itself from significant financial difficulty. BDS must leverage its relationships in the Asia-Pacific and lock down 2-3 more FMS customers for P-8 and associated systems. Last, Boeing can be expected to do everything in its power to ensure that its teaming with Lockheed Martin earns it the opportunity to build the LRS-B.

Lockheed Martin's strategy in the next 3-5 years comes down to three letters – JSF. It is critical for Lockheed to get cost and schedule under control. Recently, Pratt and Whitney have been unable to control some cost elements in the F-135 engine and this has contributed to continued scrutiny of the program writ large. With respect to Lockheed's plans to field SEA HERC, it seems unlikely. It is a best case scenario that they could fly a version of the aircraft in the next 24 months, but even if they could, it would likely be expensive and seems outside their core strategy. Elemental to their strategy, and requiring little future investment, is their P-3 sustainment efforts. They likely will continue to work closely with their partner L-3 Communications in these efforts and will also continue to provide low-cost COTS solutions to the C-130J platform, aggressively continuing to market the aircraft worldwide as the premier platform for medium lift with significant multi-mission versatility embedded. Like Boeing, Lockheed will depend on the LRS-B contract to ensure their long-term viability in the combat aircraft industry and with it, the marginalization of Northrup-Grumman.

For its part, the main task for the USG in the next 3-5 years is to provide market predictability and stability. It is clear that the aspect of sequestration-level spending will significantly impact the military aircraft market, so large programmatic decisions (like LRS-B) must be made on time so that firms can develop mitigation strategies if they are to survive. If Northrop Grumman is not selected for the LRS-B, the company could well fail – due in many respects to the market that the JSF acquisition model has created over the last 10 years.

Rotary Wing Aircraft

This analysis defines vertical lift as consisting of traditional helicopters, tilt-rotors, and compound helicopters. The recent decline in domestic defense spending has significantly impacted the U.S. defense vertical lift market. Draw-down from long ground wars in Iraq and Afghanistan, downsizing/restructuring of the U.S. Army, erosion of manned helicopter missions by UAS platforms, and the re-balance to the Asia-Pacific region combine to create an uncertain future for the vertical lift industrial base. However, platforms like the V-22, with its increased capability over previous vertical lift platforms, inspire both DoD and industry to look for new technological innovations.

The following key themes & trends inform subsequent analysis of U.S. firm strategies during the defense downtown:

- U.S. defense spending is likely to continue to decline for vertical lift programs in the near future.
- Both commercial and international military defense markets will continue to grow. For firms that are positioned well, these markets can offset domestic military programs in the near term.
- U.S. DoD is likely to take a wait and see approach to future vertical lift platforms, allowing time for technology investments to mature and the Army's strategic direction to solidify before defining specific future program requirements.
- The future structure of Army Aviation and the structure of the Future Vertical Lift program will be a major driver of corporate strategies.

Industry/Market Overview

The vertical lift market consists of civilian and military segments. The civilian market is expected to see continued growth with emerging markets in Russia, India, and China. China's expansion is largely due to an effort that began 2011 to open up low level airspace. Another region that also has shown signs of potential growth is Africa, specifically the sub-Sahara region, where currently there are only 1500 registered helicopters.[146] The Teal Group's projection of world-wide market share comparisons by major helicopter manufacturers is presented in Figure 11. Agusta Westland is the only firm of the five major firms presented that shows an increase in market share from the ten-year period ending in 2013 to the ten-year period ending in 2023.

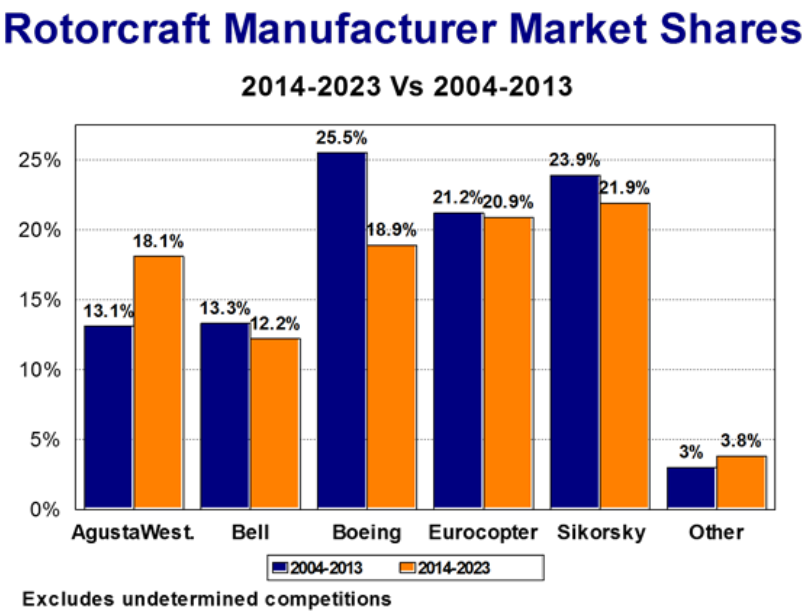


Figure 11. Rotorcraft Manufacturer market share[147]

The global military market in the next five years may reach $50 billion. This is greatly influenced by both European and U.S. defense budget declines, although some growth is still expected. India and the U.S. will remain the largest markets. The Middle East and North Africa also show potential for growth but are influenced greatly by political events.[148] Figure 12 depicts substantial U.S. market decline in 2012, but the civilian and international military markets recover to a higher level.[149] The sharp decline in 2018 is most likely due to the end of production of the U.S. Marine Corps V-22 program.

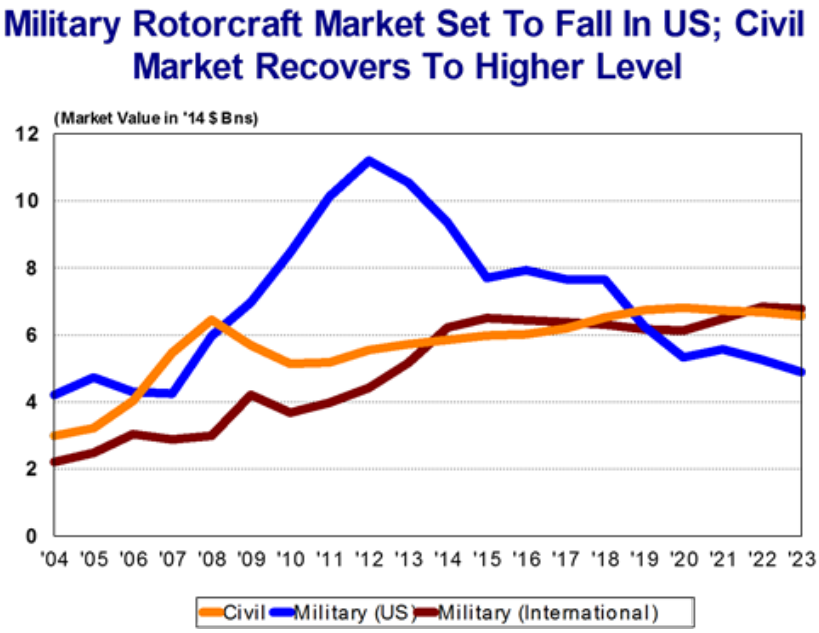


Figure 12. Rotorcraft market comparison[150]

U.S. Defense Budget and Major U.S. Defense Firms

Among aircraft markets, the vertical lift market may be the most severely impacted by the defense budget decline. Contributing factors include transition away from long land wars in Iraq and Afghanistan where helicopters were critical for operations, and the uncertain future of the U.S. Army, which has the biggest stable of helicopters in inventory. Figure 13 depicts program funding of major U.S. firms, which all see a decline with the exception of Sikorsky which is forecast to increase in 2018 due to the initial production phases of the U.S. Marines Corps CH-53K program.

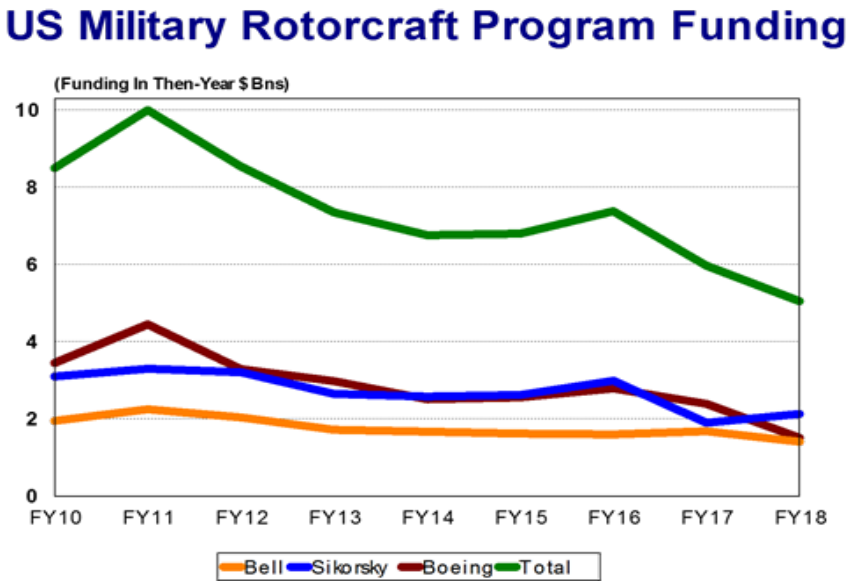


Figure 13. U.S. military rotorcraft funding[151]

An analysis of the Pentagon's five-year spending plans reveals that spending on DoD's top helicopter programs is dropping 14 percent per year and 45 percent over the multiyear plan.[152] This has had significant impact on the industry as a whole. Some U.S firms are offsetting sequestration impacts and the budget decline through foreign sales, and export demand for Sikorsky H-60 Black Hawks, Boeing AH-64 Apaches, and CH-47 Chinooks remains high.[153] Boeing has a backlog of CH-47 Chinook heavy-lift helicopters and orders for the latest variant of the Apache attack helicopter, the AH-64E.[154] However, other firms such as Bell Helicopter are somewhat late to the foreign market game, having yet to complete a sale for either their AH-1Z or UH-1Y, although there has been significant interest in the V-22 from the Middle East and Asia Pacific regions.

The U.S. military benefited from multi-year billion-dollar contracts for CH-47F Chinook helicopters and V-22 Osprey tilt-rotor aircraft. In June 2013, Boeing signed a $4 billion multi-year contract with the U.S. Army for 177 CH-47F Chinooks, and Bell-Boeing signed a $6.5 billion multi-year contract with the U.S. Naval Air Systems Command for 92 MV-22 Ospreys for the U.S. Marine Corps and 7 CV-22s for the U.S. Air Force Special Operations Command.[155]

Recently, the U.S. Army ordered Bell Helicopter to stop work on cockpit and sensor upgrades for the service's OH-58F Kiowa Warrior, as the Army plans to transfer the Kiowa's armed scout mission to Apache attack helicopters.[156] A press release from Bell stated that “the reductions in U.S. defence budgets are real and sequestration has made the future for defence spending more uncertain than ever."[157]

A significant challenge for all three major U.S. firms is the impending gap between current and future programs, especially the Future Vertical Lift (FVL) potential program. All three manufacturers have production lines that will be drawing to a close during the 2020-2030 timeframe. With the first of the FVL series of aircraft not planned for Initial Operational Capability until after 2030, strategies will be needed to hedge against lost work and revenue in the interim.

Rotary Wing: Technology

Range and speed have become increasingly important in both military and civilian markets, with the V-22 tilt rotor now in operation for over 10 years. Both military and commercial sectors are looking to achieve V-22-like performance in other platforms. Sikorsky was offering an armed compound helicopter, the S-97 Raider, for the U.S. Army's Armed Aerial Scout (AAS) program which was based on X2 technology demonstrator. Eurocopter's (now Airbus) X3 hybrid helicopter attained 255 knots in level flight on 7 June 2013, and its compound technology will be integrated into the X4 successor to the AS 365 Dauphin and the X6 successor to the Super Puma. Demand for faster, long-range helicopters for the oil and gas support market is also increasing. Agusta Westland’s AW609 tilt-rotor, based on the V22 concept, is planned to gain certification by 2016 and will complete in this market.[158]

For the DoD, the Defense Advanced Research Projects Agency (DARPA) and the U.S. Army will invest about $130 million through 2018 in new helicopter technologies.[159] In addition, the U.S. Army's FVL medium utility rotorcraft is focused on replacing the UH-60 Black Hawk after 2030, and will use the Joint Multi-Role (JMR) technology demonstrator (JMR-TD) as a base model. The JMR-TD program is the science and technology precursor to DoD’s estimated $100 billion Future Vertical Lift program, which is expected to replace between 2,000-4,000 medium class UH-60 utility and AH-64 attack helicopters after 2030. Sikorsky/Boeing, Bell Helicopter/Lockheed Martin, AVX Aircraft, and Karem Aircraft are all competing in the initial phase. It is anticipated that the JMR-TD and FVL medium rotorcraft will be a compound helicopter or a third generation tilt-rotor such as Bell's V- 280 Valor. Later, versions of the FVL are projected to replace scout and heavy lift platforms. The U.S. Army awarded the initial JMR-TD contracts in Oct 2013 with first flights scheduled for 2017[160]. Although the initial phase has been awarded, budget uncertainties make it difficult to predict the program future.

Rotary Wing: U.S. Firm Strategies

This section provides a brief summary of the portfolios of the major U.S. firms, describes the key drivers for firm strategies, and provides possible firm responses to the declining U.S. defense budget.

Table 1. Key products and market positions of primary U.S. helicopter firms

Firm	Key Product and Position
Bell	• Parent company Textron Inc. • Produce AH-1Z/UH-1Y (midway through production run). Attempting to market internationally but does not compete well against H-60 and AH-64. • Joint program with Boeing for V-22 production. Has received some foreign interest. In some cases is competing against CH-47. • Teamed with Lockheed Martin for JMR-TD and FVL (V280 Valor) • Attempting to re-ignite market share in commercial sector with (ex. 407, 429, 505, 525, Modular Affordable Product Line)
Boeing	• Produces CH-47 and AH-64. Strong sales for both internationally. • Joint program with Bell for V-22 • Teamed with Sikorsky for JMR-TD and FVL
Sikorsky	• Parent company United Technologies Corp • Builds H-60. Strong sales internationally. • Developing CH-53K for USMC • Announced as winner for USAF Combat Rescue Helicopter • Announced as winner for VXX Presidential Helicopter replacement • Teamed with Boeing for JMR-TD and FVL • Developing “Raider” (Light coaxial / pusher prop using IR&D) • Strong commercial market share. S-76, S-92

Strategy Drivers. Many of the key drivers for corporate strategies have previously been discussed, to include: U.S. defense budget uncertainty, U.S. Army re-structuring, rebalancing to the AP and the growth expected in adjacent commercial and international military market place.

An additional driver is the planned structure of the FVL program and any lessons learned that may be applied from the JSF model. A detailed discussion on the JSF model is contained in previous sections of this report. However, multiple industry representatives considered the competition for FVL to be a “winner take all” construct.

Table 2. Major U.S. firm responses to the decline in U.S. defense spending.

Industry response	Rationale
Look to or strengthen market share in commercial or adjacent defense markets	• Both domestic and international commercial markets are expected to grow. This will require a portfolio of products and support to meet customer needs such as the increase in range and speed required for oil & gas platform support, noise reduction initiatives, fuel efficiency and MRO.
Stretch out current production runs – offer mid- life upgrade options to field aircraft.	• Firms may try to extend production lines by offering mid-life upgrades or service life extensions. In consultation with Services, certain lines could be extended to maintain capacity.
Aggressively pursue Foreign Military Markets	• Markets in regions such as the AP, Africa and South America will continue to growth. Firms will look to position themselves to capture sales. An aggressive offset strategy will be required.
Invest in dual use technologies and capabilities	• Firms may consider investing in dual-use technologies both for capabilities and production processes to set up for next defense program or spending increase. Allows investment to be applied to commercial products.
Invest in R&D projects sponsored by U.S. DoD	• Firms may consider investing IR&D in projects sponsored by DoD with the intent to be able to rapidly mature and implement when funds and programs are started.
"All In for FVL"	• Firms competing for FVL are all in. It is currently being viewed as a "winner take all" program.
Teaming and M&A	• The military market may not be able to support all current firms. Continued teaming is likely. M&A is possible.

Rotary Wing: Considerations for Government

- Review lessons learned from JSF model and apply to FVL program. Specifically consider ramifications of JSF as applied to FVL on vertical lift industrial base.
- Scan industry for dual-use technologies that could easily be integrated into field platforms as performance or reliability enhancements and invest to incentivize additional industry IR&D investment.
- Continue to invest in seed money for R&D of advance vertical lift technologies in order to shape capabilities to implemented in future platforms.
- Consider implications of AP rebalance and U.S. Army re-structuring on vertical lift industrial base.
- Aggressively work with U.S industry to promote U.S. products in foreign markets through foreign military sales (FMS) or Hybrids (FMS/Direct Commercial Sales)

8. SPECIAL TOPICS

Maintenance, Repair, and Overhaul

The military MRO market provides maintenance, repair, and overhaul of aircraft and aircraft parts, sale of aircraft parts and supplies, and inspection and testing of aircraft and aircraft parts. The industry is segmented into four areas: aircraft and aircraft parts overhaul (46.9%), aircraft maintenance and repair (43.8%), aircraft parts and supplies sales, and other services. Firms compete in the MRO market in ten smaller sub-sectors: airframe heavy maintenance, engine and auxiliary power unit maintenance, component and system maintenance, avionics maintenance, repair services, interiors, modification, helicopters, aircraft line, and corporate business aircraft.[161] The top ten firms capture approximately 80% of the market, however the big four (Boeing, General Electric, General Dynamics, and United Technology Corporation's Aerospace Systems) account for 18.7% of market revenue.[162] When segmented by aircraft type, the percentage of work is reflected in the top three areas as follows: utility helicopter (33%), fighter/attack (26%), and trainer (13%).[163] Key factors impacting a firm's ability to compete in each market include: [164]

- Proximity to markets
- Effective cost controls
- Requirement for capital goods (i.e., hangars, equipment)
- Appropriate FAA licenses to operate
- Proven record of safety
- Reputation for work performed within cost and schedule requirements

While the U.S. government accounts for only 12% of the industry total revenue, its actions have significant direct and indirect effects on the industry and individual firms.

Supply Chain Management and the Military MRO Industry

From a supply chain perspective, the military MRO industry has similar range and depth and thus virtually mirrors the aircraft industry as a whole. Suppliers include OEMs, component manufacturers, material providers, and hardware producers. Distributors include independent firms, government agencies, surplus dealers, and maintenance providers in the form of government and civilian entities. Buyers include U.S. and foreign military organizations.

With the intent to better provide and receive supply chain support respectively, industry MRO providers and end users are more frequently implementing Performance Based Logistics (PBL) contracts.[165] PBL contracts hold contractors responsible for knowing the quantity and type of parts required for repair work, based on a set of readiness metrics and parameters. This incentivizes the supplier to make equipment more reliable so that costs are reduced and repair times are reduced. During routine/peacetime operations, PBLs appear to be an effective tool.

But during contingencies or war-time environments, problems may arise with the linearity and non-flexible aspects of the PBL structure.

Globalization has affected the MRO industry in many of the same ways it has impacted other sectors. Suppliers, assembly and production facilities, and purchasers span the globe, both enhancing opportunities for cutting costs and taking advantage of new markets. This has increased risk across the global supply chain by increasing dependence on foreign suppliers.

MRO: Specific Firm Positions & Analysis

Table 3. Major U.S. MRO firms and market positions

Firm	Analysis	Remarks
Boeing	● Boeing will grow their MRO fleet and aftermarket service segments, including international while continuing to acquire smaller businesses (total revenue from international business is about 30% of their total; up from 5% over 8 years).[166]	● Pursuing efforts in Asia and Israel. Also looking at Latin America for ISR and Vertical Lift markets
General Electric (GE)	● Second leading MRO firm, produces various commercial & military engines for fighters, helicopters, transport, and UAS aircraft, and has overhaul facilities worldwide.[167]	● GE has made major inroads in the Asian MRO, to include India and China.[168] Failure to win contracts for the JSF & KC-46 engines are alarming.[169] This may signal a need to re-think strategy.
General Dynamics (GD)	● Third largest MRO provider. Aviation Services and Jet Aviation business units support MRO by providing refurbishment and services at 6 locations in the U.S. & UK.[170]	● Once a thriving competitor in defense markets with F-16 program and the F-111 (with Grumman), focus is primarily commercial now.[171]
United Tech Corp (UTC)[172]	● UTC participates in the military MRO primarily through three subsidiaries; UTC Aerospace Systems, Pratt and Whitney (P&W), and Sikorsky. ● P&W appears to be well positioned for the military MRO market. ● Sikorsky: A company executive reported that approximately 80 percent of their business is in the form of MRO and sustainment. competes in the MRO with aircraft services to include spares, overhaul and repair, training, modification, ground support equipment, and logistic	● P&W: Over 1/3 of business is aftermarket. Has won several lucrative contracts: engine production for JSF and for the KC-46. Significant portion of their business is overseas (34 nations).[173] ● Sikorsky's most lucrative MRO effort is the H-60 (Black Hawk, Sea Hawk, and Pave Hawk versions). International prospects include Trinidad, Mexico, Brazil and Saudi Arabia for support of oil industry. They use regional hubs as MRO centers to increase their international footprint while remaining cost effective. (Poland)[174]
Lockheed Martin (LM)[175]	● Aside from C-130, LM appears to not have pushed for additional international MRO business. However, they are refocusing via a "presence" versus a "tenant" strategy. Domestic MRO operations occur in San Antonio at LM Commercial Engine Solutions, which caters to "nose-to-tail" modification and upgrades for aircraft built by LM, like the C-5 and P-3. ● They also conduct engine MRO on ten military and civilian engines there, and at a facility in Montreal, Canada.	● LM acknowledged the value & growth potential of life cycle sustainment and MRO, but appears not to have made it a priority. ● Configuration management (CM) problems with C-130 B-H models have plagued them due to over-reliance on sub-contractors to manage MRO. Their focus with the C-130-J is to keep a firmer hand on CM by being more restrictive in outsourcing of MRO.

MRO: Business-Government Relations

MRO businesses operating in the U.S. and under U.S. government contracts are required to operate in compliance with government regulations, including national airworthiness authority standards, federal aviation administration certifications and licenses, and USG and military rules and regulations when supporting those missions.

U.S. Government Influence

FAA compliance. The USG has wide influence on MRO firms conducting operations within the U.S. and in foreign countries. Specifically, the Federal Aviation Administration (FAA) has significant influence by regulating many aspects of the industry, such as flight operations, maintenance practices and standards, safety, technical compliance though airworthiness certificates, maintenance and repair procedures, and equipment and facilities standards. Their reach also extends to other countries where MRO operations are performed on U.S. aircraft and parts. The European Union is expected to adopt similar procedures, and other nations have begun adopting FAA-like certification procedures that restrict U.S. firms from operating locally without local licenses.[176] For sole military operations, FAA impact can range from low to significant depending on the sector of the MRO industry in which the firm is operating.[177]

ITAR compliance. During interaction with industry representatives, nearly every firm expressed concerns about the restrictive nature of ITAR. Concerns stemmed from ITAR causing increased costs in transactions, lengthy approval processes, and being too restrictive in specific parts or systems that are being marketed to foreign nations and/or militaries. However, some firms did admit to having internal processing problems that were causing bottlenecks beyond the government's ITAR approval process.[178]

DoD Influence

Defense Budgets. Uncertainty in defense budgets is adversely impacting the industry. An area of particular concern is the reduction of Overseas Contingency Operations (OCO) funding. In some cases, OCO funds were being used to preserve readiness, including accomplishing depot work for assets that are supporting on-going operations. In addition, a reduced DoD budget drives fewer flight hours for training and operations, which translates to reduced need for MRO services.

BRAC-related Issues. BRAC-related issues including consolidation of aircraft fleets, re-purposing military forces, and retiring older fleets instead of paying to modernize them, affect the military MRO industry in a variety of ways. Consolidations may reduce the demand for MRO firms that support military weapon systems, while re-purposing military forces from support roles to more core-oriented functions may have the opposite effect. Choosing to retire portions of older aircraft fleets will decrease the demand for MRO overall.

Depot 50-50 & Core. Another constraint on future MRO work are the 50-50 rules that govern the balance of work performed at DoD depots and civilian firms. According to Title 10 U.S. code 2464, Core Logistics, the SECDEF is required to identify core capabilities and ensure they are performed at government-owned and operated facilities by government employees. The 50 percent limit is imposed to limit the amount of contract work that can be outsourced to non-USG entities by each service or agency, and to preserve a core maintenance capability within the DoD.[179] Although the SECDEF can waive certain requirements, the services must justify why a core requirement should not be performed as a pure governmental function. Because government depots enjoy strong political support in Congress, this is a delicate and politically charged subject. A positive sign of change is the recent push to support public-private partnerships.

Trends in Military MRO

Table 4. MRO trends and implications

Trend	Explanation	Implications
Globalization (both in ops and support) [180]	• Increasing global operations & engagement • Changing regional importance/priorities • Extended/foreign supply chain	• Requirement for balancing cost savings with increased operations. • Increased vulnerabilities/risk for firms & DoD due to foreign suppliers • Immature MRO structure in some regions
Shifting OEM Behavior [181]	• M&A of adjacent, non-related firms • Re-capturing sustainment work • Move to "integrator" role	• Risk to IP security when partnering or merging • Decreased competition w/potential for less innovation
Rising Costs of Business [182]	• Aging workforce • Advanced technology & associated equipment, tooling, training, etc.	• Potential experience deficit & pension requirements • Decreased competition w/potential for less innovation (due to barriers to entry)
Fleet Renewal [183]	• Retiring of legacy fleets & replacement w/new aircraft	• Requirement for new MX strategies • More opportunities for competition among mature firms • Potential tertiary markets
Shifting Buyer Behavior [184]	• Changes in outsourcing focus • Increased use of PBLs	• Demand for "best in class" from industry from outsourcing arrangements • Less opportunities for third party MRO firms except in organic-level sector • Long-term contracts may improve reliability • Predictable costs & improved planning for ops
Geo-political Uncertainty [185]	• Unrest & potential hotspots • Budget dichotomy in U.S. & other nations	• Change to basing & presence construct • Potential increased Infrastructure • Increased risk to supply chain • Emphasis on commercial work over government

Other Trends and Analysis

OEM Strategies for MRO. A milestone event occurred in 2012 with the award of a major aircraft upgrade contract to a non-OEM competitor. BAE Systems won the competition for the South Korean F-16 upgrade contract over the OEM Lockheed Martin. From a historical perspective, this was unprecedented. Even though geo-politics may have had a hand in the outcome, the decision certainly has put OEMs on notice regarding future MRO business. The author assesses that this decision, combined with other pressures associated with defense spending uncertainty, will cause OEMs to re-evaluate their strategies for capturing upgrade and overhaul business on their legacy systems, as well as their approach to MRO business for new platforms. The author suspects aircraft manufacturers will exert additional control over MRO business by giving less autonomy to third party MRO firms to perform anything but organizational level maintenance. In the future, OEMs most likely will maintain a more firm grasp on intellectual property such as specialized tooling, software, and technical manuals for the weapon systems and associated support equipment they produce. For new weapon systems, OEMs likely will keep the associated MRO business close to home by outsourcing only the least technologically sophisticated work.

Legacy Platform MRO. The author also assesses the OEM positions in the MRO market by 2017 will be marked by their increased role in controlling MRO for their legacy systems. In order for OEMs to maintain a foothold in foreign markets, joint ventures between OEMs and host nation and/or host region firms mostly likely will become the norm. It will be increasingly difficult for independent MRO firms to compete with OEMs due to inaccessibility of technical data and intellectual property from OEMs. In order for independent MRO firms to survive, they will have to focus on organizational level maintenance vice major upgrades and overhauls/repairs. Retiring legacy airframes that are being replaced by new platforms equates to less MRO business for upgrades and overhauls in the near term, and less chance for independents garnering MRO business for new aircraft.

Supply Chain M&A. In the mid-term, it appears supply chains for MRO will contract based on OEMs trimming suppliers in order to maximize revenue. This contraction will most likely lead to suppliers following in the prime's footsteps by consolidating through mergers and acquisitions of smaller companies. Rene Ouimet and Bob Willen of DefenseNews presented the following four scenarios as it related to supply chain consolidation.[186]

- Economies-of-scale-driven consolidation by aggregation or reconfiguration. As companies reconfigure by aligning or trading similar parts of their business based on programs and economic models, it avoids anti-trust concerns — and may well fuel new competition and innovation — that benefits not only the military, but shareholders, employees and taxpayers.

- Complementary knowledge-based consolidation. Knowledge-based companies may be more prepared to deal with the structural changes, but they could still

benefit from complementary consolidation. This would expand the scope of their offerings, creating greater differentiation and making it more difficult for competitors to keep pace.

- Exit of weaker, low-value-add players. There are low-concentration sectors in which many small companies produce low-value-added products.

- Merger of knowledge-based with traditional infrastructure companies. While this scenario is plausible and makes economic sense, it provides little relief if demand has sharply fallen. Nonetheless, there are some logical combinations that could create future value and eventually transform some larger infrastructure companies into stronger, higher-value companies.

Higher Barriers to Entry. In the long term, firms wishing to enter the MRO market will have to be well financed in order to acquire the capital goods necessary to compete for and eventually complete MRO-type work. Even new entrants that are well financed may have difficulty competing against established firms. To mitigate the associated risk of going head-to-head with established firms, new entrants may pursue niche markets and/or become involved in private and public partnerships where they can leverage their competitive advantages.

MRO: Diagnosis of key issues

Role of Technology in the Military MRO Industry. Technology plays a large part in the costs seen throughout the MRO industry. The investment of capital in technology is assessed to continue to grow over the next several years as firms search for competitive advantage and cut expenses.[187] As aircraft, weapons, avionics, engines, stealth technology, UAV systems, etc. become more technologically advanced, MRO-related technology must also advance to keep up. The advancement of computer-facilitated fault monitoring and analysis as a more permanent feature in aircraft and related systems may drive the need to consolidate repair centers because the cost of required infrastructure will be too expensive to maintain at each individual base. In order to save money, the U.S. Air Force is moving away from maintaining intermediate repair capabilities at every base and toward the concept of centralized repair facilities.

Another important aspect of technology involves the increased use of composite materials in aircraft. Composites add complexity for MRO, particularly when a repair must be performed in field or austere locations that may not have OEM or depot capabilities. However, technological advancement of composite repair capability is enabling some repairs to be conducted in the field as the capability becomes more prevalent. This is an area where the capability of MRO has slightly lagged the technological advances in aircraft manufacturing materials.

As DoD focuses more on the Asia-Pacific (AP) region, it appears that a more rotational, warm-basing construct will become the norm. In order to support this paradigm shift, and the

technologically advanced aircraft and systems that will be required, MRO constructs will have to be adaptable. According to a recently released report from CSBA titled "Toward a Balanced Combat Air Force", long-range aircraft "capable of overcoming the region's tyranny of distance" and "less reliant on non-stealthy aerial refueling aircraft and close-in theater bases" will be required in the AP.[188] An MRO infrastructure and capability must be developed that complements any operational constructs implemented in response to new strategic considerations.

Another technological advancement, Adaptive Manufacturing in the form of 3D printing, is becoming more pervasive in the aircraft industry. This will lead the MRO industry to also embrace its use, and in the short term drive costs up as firms strive to acquire the capability, before delivering cost savings in the long term. As an example, General Electric plans a $13 billion investment in this capability within the next five years.[189] In addition, 3D printing raises the level of risks of counterfeit parts entering the supply system. This risk is only magnified by the global nature of the supply chain.

It is the author's impression that in the short term, technological advances will increase MRO-related costs, but over the long term will lead to cost reductions. The challenge for MRO firms and the USG/DoD will be to remain focused on the long game, and plan for lifecycle costs early with early investments in sustainment technologies that complement weapon system advancements.

JSF model as precedent for future military MRO programs. The future of military aircraft and the MRO industry appears to be following the JSF model. Dozens of firms and nations that span the globe produce parts and have a stake in development of the platform, as well as procuring first-run models. Richard Abuolafia called the JSF "an industrial strategy, as much as it is a fighter, for the U.S. and other nations that choose to take part in the program from a buyer, developer, and partial manufacturer perspective."[190] As discussed in previous sections of this report, it has the potential to have significant negative impact on the fighter industrial base and future competition.

Considerations for the MRO Industry

Table 5 below presents recommendations for government and industry and identifies common areas where greater efficiency can be achieved.

Table 5. Government and industry considerations for MRO

Considerations	USG/DoD	MRO Firm/Industry	Common
"Match" National Security Strategy and Plans w/Industrial Capabilities	X	X	X
Fully Consider Implications of AP Rebalance	X	X	X
Use Successful Programs as Models	X	X	X
Revisit/Shore up ITAR Processes	X	X	X
Integrate Civilian & Military MRO Best Practices	X	X	X
Become Fully Vested in Aftermarket/Sustainment		X	
Re-consider 50-50 Depot/Core	X		
Re-visit Contract Constructs	X		

"Match" National Security Strategy and Plans w/Industrial Capabilities: USG/DoD should take the lead in teaming with industry to ensure MRO industrial capabilities, including advances in procedures and technology, remain in lock step with an evolving national security strategy, changes to operational concepts, and current operations.

Fully Consider Implications of Asia Pacific Rebalance: The USG/DoD should fully study the long term impact that the rebalance to the AP will have on MRO industrial capabilities, and adjust planning factors and funding to compensate for necessary changes in MRO to support operational requirements. Specific attention should be given to assessing the impacts of the JSF sustainment model on AP operational and logistical concepts.

Use Successful Programs as Models: Both military MRO firms and USG/DoD should use successful programs, such as the C-130 and H-60, as models for future MRO programs and partnerships.

Revisit/Shore up ITAR Processes: Industry should expedite any internal re-structuring requirement to rapidly and efficiently take advantage of the Export Control Reforms that have been put in place (discussed further in the foreign market section). In addition, government should continue to look for ways to improve ITAR controls and processes to benefit the U.S. MRO industry.

Integrate Civilian & Military MRO Best Practices: The USG/DoD should seek and apply best practices from civilian industry such as consolidation of MRO operations into regional hubs, specialization in areas where entities have a unique competitive advantage, and collaboration, coordination and integration of MRO activities at the strategic level.

Firms Should Become Fully Vested in Aftermarket/Sustainment: Firms should accept, and become fully vested in developing long term business strategies for sustainment MRO, especially in a time when defense budgets are uncertain and trending downward.

Re-consider 50-50 Depot/Core: The USG should examine the 50-50 rules that govern the share of work performed at DoD depots and civilian firms, and consider updating the rules in light of changes in strategically important industries.

Re-visit Contract Constructs: The DoD should strive to, whenever possible, establish MRO contracts with industry for long-term contracts, make the swift award of contracts a priority, and ensure PBL-type contract constructs are scalable and flexible enough to deal with changes in operating environments.

Foreign Markets and Competition, Export Controls, and Offsets

Due to waning domestic defense spending, U.S. aircraft defense firms are likely to look to foreign markets to augment their domestic portfolios. As a result, firms are placing a greater emphasis on exports in corporate strategies. This section addresses recent global defense spending trends, defense trade markets including recent U.S. foreign military sales, potential factors for corporate strategies in foreign markets, recent export control reforms, and offsets.

Global Defense Spending

Total global defense spending in 2013 was approximately $1.70 trillion. Procurement accounted for $600.00 billion and is expected to have a 1.9% CAGR through 2018. The Asia-Pacific region has the greatest expected defense procurement growth rate at 5.0%. Command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR) was the largest technology segment at approximately $100 billion in 2013. Lockheed Martin was the top global defense firm in 2013 with about $35.50 billion in contracts accounting for 5.9% of the market. The top 10 global defense firms accounted for $214.20 billion for 35.7% of the market.[191] Figure 14, from IHS Jane's, depicts total global defense expenditure projections through 2023 by region.

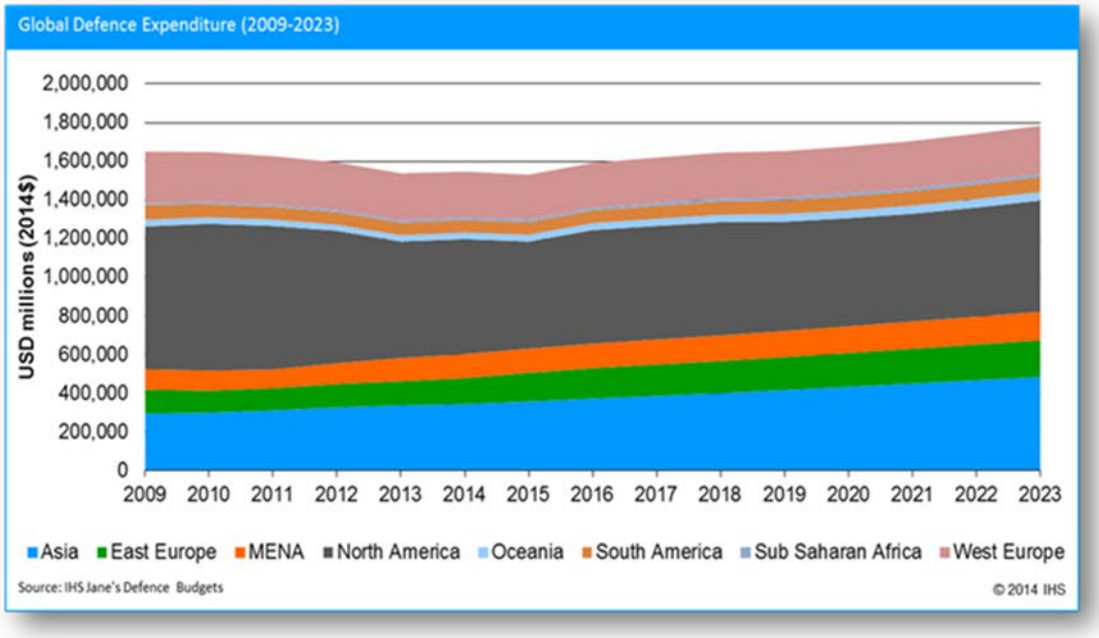


Figure 14. Global defense spending projections 2009-2023[192]

Global Defense Procurement. A few key trends in global defense procurement are emerging. The countries with the highest projections of growth are in the Asia-Pacific and Middle East/North Africa (MENA) (see Figure 15). This is most likely due to a perceived threat

and/or rising tensions with China, North Korea, Iran and Russia respectively, combined with an uncertainty about U.S. foreign policy in these regions. Each of these is driving regional countries to unilaterally build their own defense capabilities. Top budget requests consist of C4ISR capabilities and fixed wing aircraft, as well as ships. Current fleets are also reaching the end service life, driving the need to either upgrade/modernize or replace with new platforms. Total global defense spending on procurement between 2013 and 2018 is expected to reach $3.79 trillion.[193]

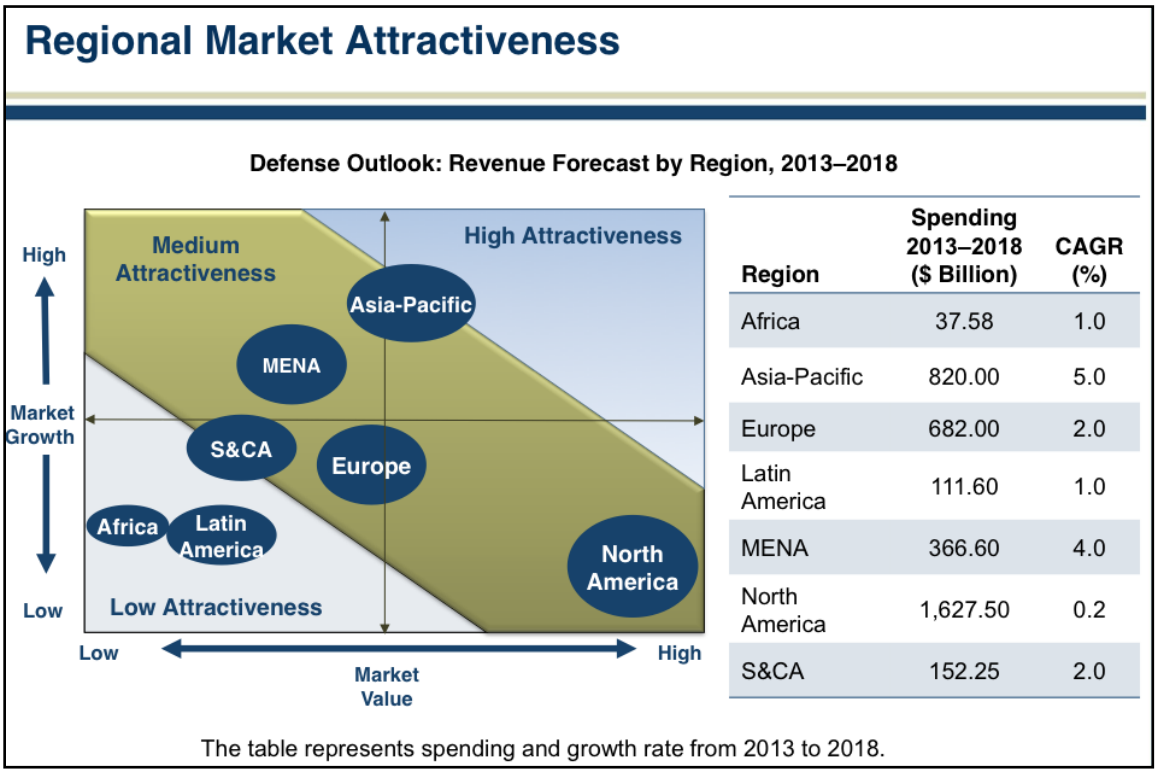


Figure 15. Frost and Sullivan revenue forecast by region[194]

Global Defense Trade and U.S. FMS

Global defense trade and the need to import defense goods also continue to steadily rise. In 2012, the total amount of defense trade rose to over $73 billion as compared to just over $56 billion in 2008.

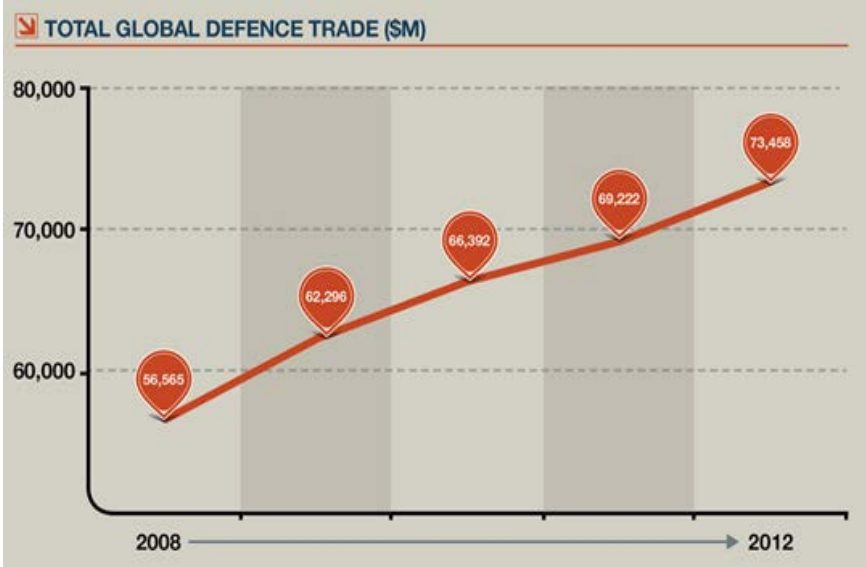


Figure 16. Global Defense Trade Volume 2008-2012[195]

The aircraft segment remains the single biggest global export segment (see Figure 17 for breakdown of 2012 totals.) Competition is high in markets such as rotorcraft, aircraft subsystems, non-stealth combat aircraft, training aircraft, and the upgrades. In countries that possess indigenous aircraft industrial bases, U.S. firms posses an inherent disadvantage in competitions. However, U.S. firms still enjoy advantages in technology, U.S. interoperability, and MRO/sustainment. The result is that partnering with indigenous companies or providing offsets is required in order to win new contracts. Offsets will be discusses in detail in a later section. Total world-wide military aircraft market projections by country and function as well as UAV market projections by end-user country are graphically depicted in Appendix 1.

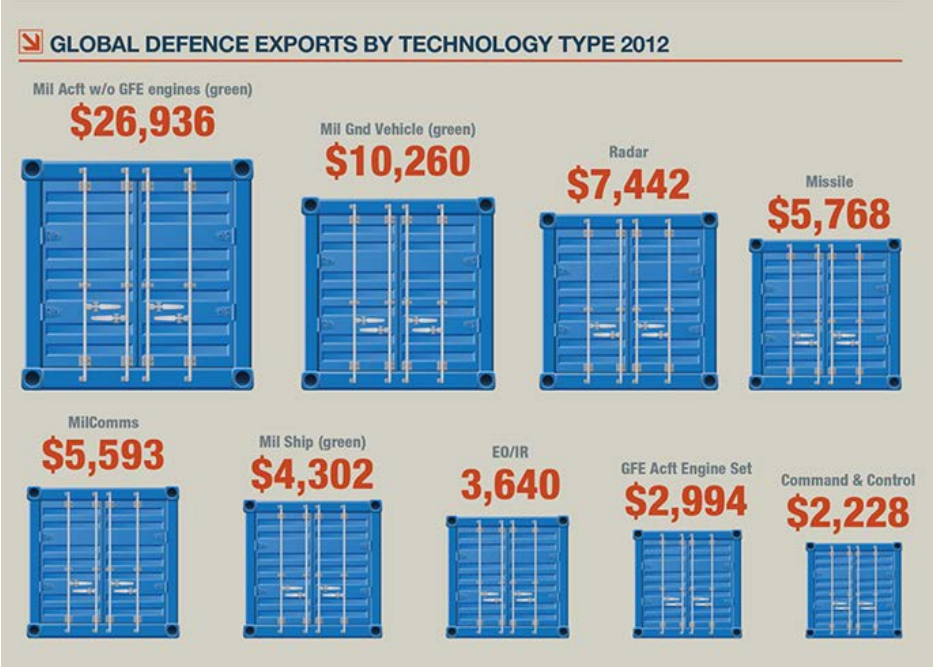


Figure 17. Global defense exports by technology (2012)[196]

U.S. Foreign Military Sales. Many aircraft and aircraft systems require involvement of the foreign military sales process (FMS vs DCS will be discussed in a later section). FMS agreements have historically been a strong market for U.S. firms. These sales, just like other markets, offset in the short term the decline in U.S. defense spending and enable sustainment of the industrial base. From the U.S. government perspective, FMS helps to build coalitions and interoperable weapons with friendly countries.[197]

Department of Commerce Bureau of Industry and Security reported that from 2010-2012, aircraft manufacturing was 62.9% of the total value of defense export sales contracts.[198] In 2012, significant contracts were awarded to Saudi Arabia for F-15s, Oman and Taiwan for F-16s and India for C-17s. In addition, South Korea recently announce the F-35 as the winner of its fighter competition. However, F-35 delays continue to have some negative impacts on FMS with countries such as Canada and Japan waffling on the total quantities that they will procure. Another potential increase in FMS is due to greater international interest in the V-22 Osprey. Countries such as UAE, Canada and Israel are all showing significant interest.[199]

Factors Affecting Foreign Competition for U.S. Aircraft Firms.

Competition in foreign markets can be broken down into four basic elements: product, affordability, offsets, and politics. First, the product has to meet the requirements/needs of the buyer. Second, although defense budgets are going up in some regions, affordability is still a concern especially when there may be multiple security needs to fulfil. Third, buyers are no longer seeking a simple product transaction. Instead, they want a package deal that incorporates

offsets to benefit their economy and industrial base. Lastly, political relationships play a significant role. When a buyer purchases an aircraft from a firm, they are signing up for a relationship that may last 20-30 years with both the firm and the firm's origin country. Each of these factors can tip the scale in one direction or the other for any competition. This calculus has created a number of factors that are affecting corporate foreign sales strategies in the aircraft sector.

- Entering foreign markets is not necessary easy. Firms that have had long standing relationship with foreign partners may find it easier to gain business than those that have only recently implemented the business structures to deal with the foreign market environment. Thus, new entrants are unlikely to see benefits from the foreign market in the near term.

- Foreign markets are increasing becoming buyers' markets. This has resulted in increased demand for high tech products, technology transfer, and industrial participation requirements that accompany foreign sales. Foreign markets have become less about the transaction and more about the packaged deal and relationship with the seller to include offsets. Increasingly, countries make arms acquisition decisions for reasons other than technical superiority, interoperability with the U.S. military, follow-on service, or loyalty or political alliances. Therefore, U.S. weapons producers must create international business strategies that meet the realities of the current market demand.

- U.S. aircraft and aircraft components have increasingly become higher tech, which comes at higher price tag and creates potential exportability challenges related to ITAR controls. Each makes it more difficult to export U.S. goods. High cost platforms such as the F-35, KC-46, and P-8 may lose to cheaper alternatives with less but acceptable performance offered to buyers from foreign competitors. In sectors such as 4th generation fighters, tankers, and maritime surveillance, this is creating high competition.

- The JSF industrial model is stressing foreign sales and strategic partnering nations' options. The F-35 is only offered to a select group of countries, and in many of these countries, the quantity of aircraft to be purchased is uncertain. The irony of the strategic partnering intent of the F-35 is that the uncertainty leads to an increase in unit cost and thus reduces the options of partners to resource other capabilities required for partner capacity such as the UAS, P-8 and KC-46 tankers. Second, markets where the F-35 is not being offered have become very competitive, increasing the difficulty for U.S. manufacturers of 4th generation fighters to win (see further analysis in the fighter market section of this report).

- Lastly, hybrid foreign sales cases have become prevalent as some foreign buyers want to deal with commercial industry instead of the U.S. government. Hybrid cases, which are a combination of foreign military sales and direct commercial sales, balance the interests of U.S. firms to compete in contested markets while protecting government's legitimate

policy concerns to protect certain technologies and control proliferation of certain military weapons and capabilities.[200] Figure 18 below contrasts the differences between pure FMS and DCS sales.

FMS and DCS Program Comparison

	FMS	DCS
Financing	FMFP is an option	No financing help from the USG. There is an exception provided for ten countries*.
Politics	Establishes a political/military relationship with the USG	Allows countries whose populous may have a negative image of the US to purchase US arms without the stigma of a relationship with the USG
Program Cost	Customers can benefit from economies of scale when FMS orders coincide with DoD procurement	Contracts may or may not include final contract pricing and normally do not incorporate the total package approach
Estimated Cost	Actual program costs are often less than LOA estimates, but this is not guaranteed	Allows for firm-fixed pricing

Note: *The countries permitted to seek FMFP for DCS can be found here.

Source: Frost & Sullivan

Figure 18. Comparison of FMS and DCS[201]

Export Controls

Export controls are designed to promote international peace and security by limiting the destabilizing accumulation and proliferation of weapons. Conventional wisdom is that relaxing controls on U.S. weapons technology exports would increase U.S. weapons manufacturers' ability to penetrate overseas markets. The call for relaxed restrictions grows during defense downturns because international weapons sales are a primary mechanism to counterbalance the decline in domestic sales. In making export control decisions, the U.S. government balances industrial base needs with more traditional security and foreign policy goals. At the same time, government and industry work to ensure that transfers do not undermine U.S. technological superiority. Therefore, a government's decision to diffuse military technology, and to whom, is intrinsically linked to international power dynamics.

Export Control Reform

U.S. producers have voiced concerns about the way the United States implements export controls, especially as they relate to interoperability issues and third party re-export rules. To address their concerns, President Obama established the Export Control Reform (ECR) Initiative to restructure how the United States conducts arms control. Through the ECR, the U.S. is adjusting its export control processes to reduce the regulatory burden for U.S. industry while maintaining controls over exports of specific defense articles. The changes made through ECR consider the needs of the defense industry without sacrificing the public good of security, which is a vital function of government.

The ECR Initiative began in August 2009 with a broad-based review of the U.S. export control system.[202] The review concluded that the current export control system was overly complicated, contained too many redundancies, and, in trying to protect too much, diminished U.S. ability to focus efforts on the most critical national security priorities.[203] Primarily, the ECR reforms the existing export control system to improve interoperability with allies, strengthen the U.S. defense industrial base by reducing incentives for foreign manufacturers to "design out" controlled U.S.-origin parts, and ease licensing burden on U.S. exporters.[204]

The ECR is a process change, not de-control of military items. The ECR will benefit secondary suppliers in the maintenance, repair, and overhaul industry more than it will help principal manufacturers or integrators. In addition, because the changes to license requirements are applicable only to parts and components, it is unlikely that ECR will play a role in opening additional international markets for U.S. defense platforms.

To implement ECR objectives, government agencies are revising their respective control lists to create a positive list on the U.S. Munitions List (USML) and to move certain munitions parts and components from the USML to the Commerce Control List (CCL). The newly designated items on the CCL still would be controlled as military items, but in a more flexible way, especially with regard to allies and partners. In addition, the newly designated items would

be eligible for country and transaction-based license exceptions and the *de minimis* rule. In other words, certain exports would no longer require licenses even though the items are on the CCL because the transaction is eligible for a license exception. Further, with the application of the *de minimis* rule, for most ultimate destinations, foreign-made items incorporating 25 percent or less of BIS-controlled U.S. parts would not be subject to U.S. re-export licensing requirements.[5]

Export Controls or Business Practices

In a study on export controls and the U.S. defense industrial base, the Institute for Defense Analyses analyzed the satellites and machine tools industries and found that differential application of U.S. export controls vis-à-vis other nations did not account for the loss of U.S. market share.[205] Rather, the study concluded that rising foreign competency and natural industry cycles seemed to account for the drop.[206]

Similarly, aircraft companies, during industry study visits, did not reveal any instances of lost sales to a foreign competitor due to delays or conditions in U.S. export licensing. Further, they did not seem to challenge the need for export controls of advanced weapons and associated technology. When the companies did voice concerns about export controls, it was about the process of obtaining licenses rather than about the controls themselves. At the same time, they added that with advanced planning on their part they could overcome the procedural delays in obtaining export licenses. In addition, in a conference on Europe's defense market, neither EU Member States nor industry questioned the need for controls. Rather, as is the case with U.S. counterparts, the major complaints were about national implementation processes.[207] To the extent that export controls do play a role in international sales, it is the procedure of obtaining licenses, rather than the control of the technology itself, that most impacts sales.

[5] The de minimis rule is not available for China and other countries that are subject to arms embargoes. For those countries, for items transferred from the USML to the CCL, the "see-through" rule would continue to apply just as it is under the ITAR.

Offsets in Foreign Sales

Offsets have become significant decision criteria for buyers as they place greater demands on exporters for purchasing their defense products. More than 120 defense export recipient nations currently require offsets for weapons purchases.[208] Offsets have become increasingly important to buyers as they attempt to strengthen their industrial base and promote economic growth through technology transfer and industrial participation.

Offsets Defined

The U.S Department of Commerce Bureau of Industry and Security (BIS) describes offsets as encompassing a range of industrial and commercial benefits provided to foreign governments as an inducement of, or condition to purchase, military goods or services. Offsets can include a single effort or a combination of co-production, licensed production, subcontracting, technology transfer, purchasing, and credit assistance. BIS also states that the U.S. government considers offsets to be economically inefficient and trade distorting and prohibits any agency of the U.S. government from promoting or committing U.S. firms to offset arrangements in conjunction with the sale of defense products.[209] But in practice, offsets are a reality and an increasingly important factor in the international defense marketplace.

Industry firms must proactively address offset requirements if they are to be successful in exporting their products. This is especially true for the aircraft industry where aerospace related offsets are frequently a national priority and many countries seek offsets as a path to building or strengthening their own indigenous aircraft capabilities and gaining spillover technologies that can applied to other sectors. BIS reported that from 2010 to 2012, aircraft, engine, and engine parts manufacturing were the top three offset categories, combining to equal 43% of the total value of all reported offsets.[210]

Offsets are categorized as either direct or indirect. Direct offsets specifically relate to the defense product being exported. Indirect offsets do not relate to the defense product, although they may be related to other military capabilities. The nature of the offset, either direct, indirect or a combination, is often based on the maturity of the buyer's industrial base and the buyer's national economic goals. Buyers perceive offsets as a stimulus to the local economy and seek to justify the purchase of foreign products by highlighting the economic benefits of defense offsets.[211] Buyers may also seek to limit negative impact to a domestic industry by requiring relocation of work from a supplier's origin to the buyer's country. Offsets may also be linked to non-military products.[212] Sellers have historically desired indirect offsets because they provide more flexibility and have lower associated costs. This is important because offsets generally result in an increase in the acquisition costs of the imported defense product.

Offsets are a growing barrier to exports

During the Cold War era, the U.S. defense industrial base largely did not depend on overseas sales. Defense budgets were sufficient to sustain military needs and to ensure a healthy aircraft industrial base. Instead, the U.S. government predominantly used foreign sales for political and foreign policy goals. This dynamic changed with the end of the Cold War. The United States became more reliant on foreign markets as defense budgets declined. Domestic firms now had to compete with foreign producers such as Great Britain, France and Germany, which had established international relationships and were already reliant on foreign defense sales.[213]

The resultant environment frequently led to high competition among supplier nations to secure sales. Buyers began demanding a higher level of technological sophistication in the systems being procured and leveraged the new market dynamic to demand greater benefits from offsets agreements, including an increasing demand for technological transfer, higher offset percentages, and higher local content requirements.[214]

Offset progression depends on industrial capabilities

Offset demands generally progress based on the maturity of the buyer's indigenous industrial capabilities. IHS Jane's divides offset demands into seven levels, excluding those countries which reject offsets.[215] The levels are graphically presented in Figure 19.

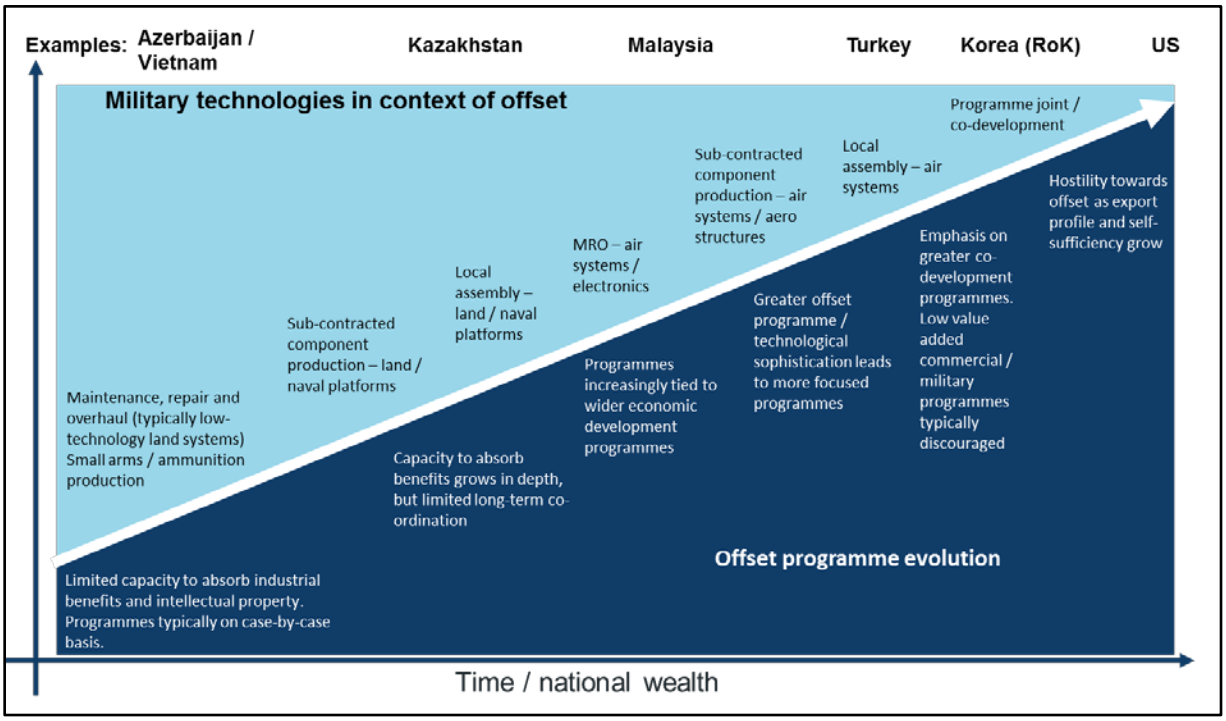


Figure 19. Offset evolution[216]

Offset Trends

Global economic uncertainty and a greater emphasis on aligning offset objectives with national economic goals is creating a greater need for balancing procurement with offset requirements. Harmonization of a nation's offset demands with its plan for national economic growth as well as increasingly non-defense oriented offsets are posing a greater challenge to U.S. defense firms[217] No longer is the transaction alone enough to satisfy buyers. Technology transfer and long term sustainment of offset packages are becoming just as important if not more to decision makers[218] as buyers are moving away from countertrade and low value added industrial participation.[219]

As offsets have evolved, a set of general trends have emerged. Buyers are requiring offsets by law to generally 100% of contract value and for a contract minimum as low as $5 million. Counter-trade and low value added offsets are being replaced by high valued offsets specifically for technology transfer. Penalties for failing to meet offset obligations are being codified into law, and buyers have an expectation that offsets may reduce acquisition costs. Buyers generally believe that offsets will result in job creation and economic development including sustainable work beyond the acquisition period. The regions with the highest expected growth of military offsets are the Asia-Pacific and Middle East.[220] Finally, buyers believe that offsets containing technology transfers are key to future economic growth.[221]

Offsets: U.S. Aircraft Industry Perspective

With the emergence of offsets as a significant factor in the foreign marketplace, suppliers are finding it increasingly difficult to balance the need for a sale with the potential risks associated with advanced offset requirements. Table 6, although not inclusive, provides an additional summary of observations from multiple U.S. defense aircraft firms on offsets. It reinforces the complex and difficult nature of offset negotiations and compliance.

Table 6. Offset observations from interactions with selected aircraft industry firms

Firm A	● Industry has not factored in structure changes to address offsets. Business structures have to change, partnerships must be in place, markets must be forecasted well in advance, and relationships created well before competition. ● Complexity of offsets is ten times greater than 20 years ago. ● Lots of tension exists on offsets between firms and customers especially as it relates to what qualifies as and the overall value of the offset. ● Offsets used to be about how much you could build in the country, now it is about much more.
Firm B	● It is difficult to compete well in a large offset environment. ● Foreign sales are much more sophisticated and customers are different. Sales are no longer transactional. Offset proposals must be well thought out and creative so as to not adversely affect the overall price of the contract. ● Government and Industry are not aligned with respect to what can and cannot be transferred. ● Offsets are a dysfunctional process especially when collaborating with partners. ● Industry is often out matched by foreign firms in a competition that have heavy political and government backing. ● Negotiating the value of offsets with buyers is a very difficult process.
Firm C	● Offsets are very challenging especially for a vertically integrated company. ● Countries want a different type of offset because they want to build their own defense products.
Firm D	● Offsets are a significant issue to deal with.
Firm E	● Countries see offsets just as important as the product.
Firm F	● We are very conscience and methodical in dealing with offsets and concerned about making competitors. This leads to a very slow and deliberate process in offset strategy development.

As evidenced in the table, firms are cautious and reluctant when addressing offsets. Often they are prepared to transfer lower technology elements of defense production such as sub-component manufacturing and repair and maintenance capabilities, and tend to retain the high technology and high value capabilities of their companies at home. This strategy is not without consequences, as it can reduce domestic workforce and potentially increase the risk of loss of a domestic supplier base, especially for small businesses.

Offsets Implications

Government and industry must actively manage the risks associated with implementing offsets. Understanding the risks enables industry to develop offset strategies that do not jeopardize key capabilities and allows the government to establish policy that protects the nation's interests.

Table 7. Offset implications for U.S.

Technology Transfer	• Creates competitors from customers (Industry) • Tech diffusion may shape/change regional security environment (Gov)
Industrial Participation	• Over-reliance on foreign suppliers • Out-sourcing to immature industrial base – can it be sustained?
Globalization of supply chain	• Reduced domestic demand – foreign reliance • Job transfer away from U.S. small businesses
Increases resources required to manage	• Industry requires business structure to propose, execute, manage, and track offset agreements. This may take attention and resources away from more critical U.S. programs

With respect to the additional business structure and resources required, Figure 20 depicts a subset of offset obligations from select defense firms through 2022, showing the magnitude of offset effort, execution, management and tracking.

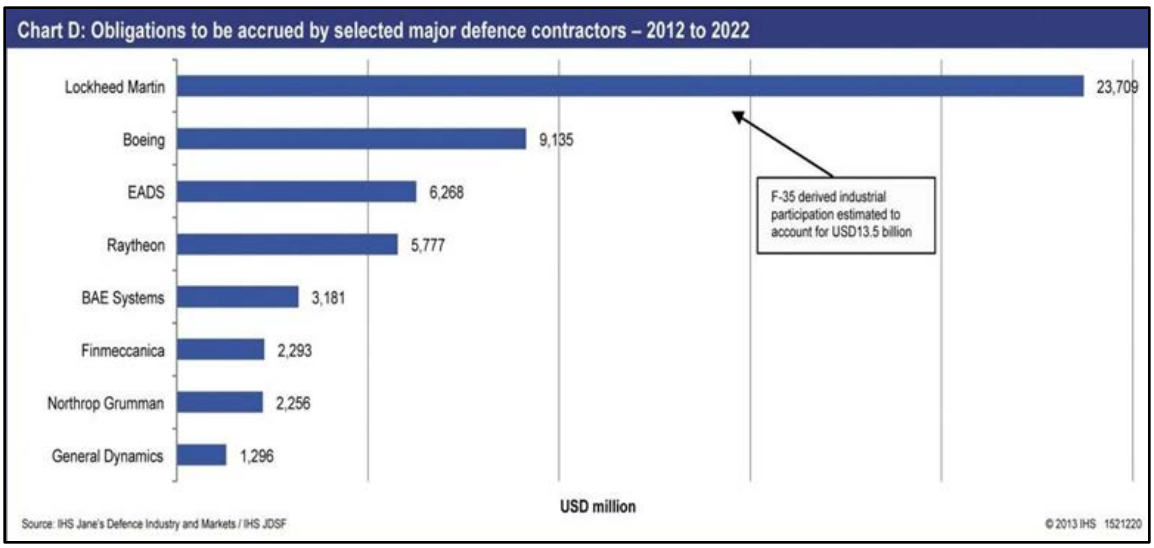


Figure 20. Offset obligations by major firms, 2012-2022

Government and Industry Considerations/Actions

Table 8 summarizes considerations and actions for both government and industry to better account for offsets in the foreign marketplace.

Table 8. Consideration for U.S. with respect to offsets

U.S. Considerations	
Offset teaming	In order for firms to be successful in the offset market, an internal business structure to address offsets and a robust network of offset partners and advisors must be developed that can more effectively address complex offset requirements.[222]
Building foreign relationships	Firms must embrace offsets as a standard business practice and begin establishing relationships with potential foreign partners and oversight government agencies well in advance of a campaign.[223]
Link Offsets to Buyers' industrial capabilities	Offset proposals should be linked to the buyer's industrial capabilities and relevant research and development programs to maximize chance for long term success.[224]
Implement Corruption Risk Assessment	Firms should consider internal corruption risk assessment processes to avoid negative consequences on reputation and profitability.[225]
Implement a strategic assessment of technology trends	USG should development a comprehensive technology assessment that defines both the current environment and future technological environment to feed national security strategy development.

Aircraft Industrial Surge Capacity

The aircraft industry plays a leading role in providing DoD the resources needed to protect U.S. national interests. The structure of the industry, and the interaction between government and industry, inform an analysis of industry's response to the defense spending downturn. One area of concern is the capacity of the aircraft industrial base to adequately respond to government requirements for support of protracted military operations in a contested environment. In this scenario, the United States would need a robust aircraft industrial base that can outperform a competitors', and perhaps even outperform the combined industrial bases of several competitors. But U.S. aircraft industrial mobilization capacity has been slowly eroding due to program infrequency and reduced defense spending, which have resulted in firm consolidation.

The U.S. should consider developing a strategy for managing potential aircraft combat losses with reduced, closed, mothballed, or even current aircraft production capacity. DoD and the aircraft industry must find ways to bridge any short order manufacturing deficiencies so that the capacity to respond to DoD's call to rapidly build facilities and ramp up aircraft production is preserved.

Concerns with surge capacity

The following factors were identified as affecting aircraft production rates and/or sustainment capability during protracted operations.

- ***Minimal tier 1 suppliers to design, develop, integrate, produce and sustain military aircraft.*** As the supplier base shrinks, so does the defense industrial contractor's ability to surge. Although a single contractor could provide adequate aircraft quantities if resources were available, most firms maintained that they have a maximum production rate based on the tooling currently available. Within the scope of this research, considerations for additional surge capability did not appear to be a factor in the amount of production tooling available.

- ***Large aircraft primes are heavily dependent on lower tier suppliers*** (2^{nd}-4^{th} Tier) for delivering parts during a surge, and the availability of raw materials may delay increased production. Most firms interviewed as part of this research stated that they could reach some level of surge capability based on the requirements which they control. However, all stated that both supplier components/hardware and materials would be "lead time away" and ultimately negate any capacity the prime had.

- ***"Just In Time"(JIT) supply and inventory models may result in significant production delays*** if a surge in parts is required. "The primary disadvantage to JIT is its relative complexity...Supply-chain relationships require retooling that involves multiple suppliers, closer locations, or companies that can supply materials with little

advance notice."[226] This supply philosophy is counter to maintaining a surge capability, as there are no extra parts or material available to respond to an unforeseen increase in requirements based on an un-forecasted contingency.

- ***Performance Based Logistics (PBL) may not be the right structure*** to support sustainment efforts caused by a surge in response to a contracted conflict or contingency. A sudden request to surge in capacity is the equivalent of severely under-forecasting the production or sustainment requirement. In interactions with industry representatives who deal with PBLs, there appeared to be little thought of how to respond under the current PBL construct to a surge in maintenance or sustainment requirements without being "lead time away."

- ***Production line supply sources may not have adequate resiliency*** to account for surge requirements. Many firms noted several instances of single sources of certain components. In the opinion of one industry executive, there are not enough bearing manufacturers, casting companies, and foundries within the U.S. to provide additional sources of supply and allow for more competition among suppliers.[227]

- ***The current process to close and/or mothballed production lines*** may not preserve sufficient capability to respond to a protracted conflict or contingency that requires replacement of combat aircraft losses. Even if a production line can be re-started, there are still concerns with getting skilled labor and suppliers for material and parts. Once laid off, employees tend move on and take other jobs, while suppliers terminate their own production runs and move on to other business opportunities.

- ***Co-dependent production lines*** such as the F-15 and F-18 at Boeing rely on each other to maintain both cost and production efficiencies. If one of these lines closes, the cost for producing the other aircraft will increase significantly.

- ***Today's manufacturing processes are highly specialized and require proprietary, critical machinery.*** In order to obtain a manufacturing advantage, precision milling machines are designed to perform specialized and innovative tasks. Some of these machines are proprietary with only one machine manufacturer. Although defense contractors strive for multiple sources of supply, some key parts are only produced in-house.

Preserving Surge Capacity

The following discussion is intended to highlight one method for preserving surge capacity in aircraft production by using the F-16 production line at Lockheed Martin as an example. In this example, lead time for critical components is the limiting factor in surging production to full capacity. To offset this lag, one possible solution is the stockpiling or pre-staging of long lead items that are required in the production process. This includes parts or components of the aircraft that are not readily or immediately available from suppliers to support

an urgent requirement. For the purposes of illustration, an arbitrary 12-months' worth of pre-staged material was chosen. Graphical comparisons between possible postures of a production line are shown in Figure 21. The F-16 line is currently producing 1.5 fighters per month and has tooling in place to produce 6 per month. Table 9 compares four scenarios.

Table 9. Industrial surge scenarios

Scenario	Pre-stage (12 months worth)	Normal long lead items (months)	Ramp rate to 6 a/c per month	Time to full max production capability (months)
Open line	No	18	1 a/c per month after 17 months	21
Open line	Yes	18	1 a/c per month	5
Re-start mothballed line	No	18	1 a/c per month after 17 months	23
New line	No	18	1 a/c per month after 23 months	29

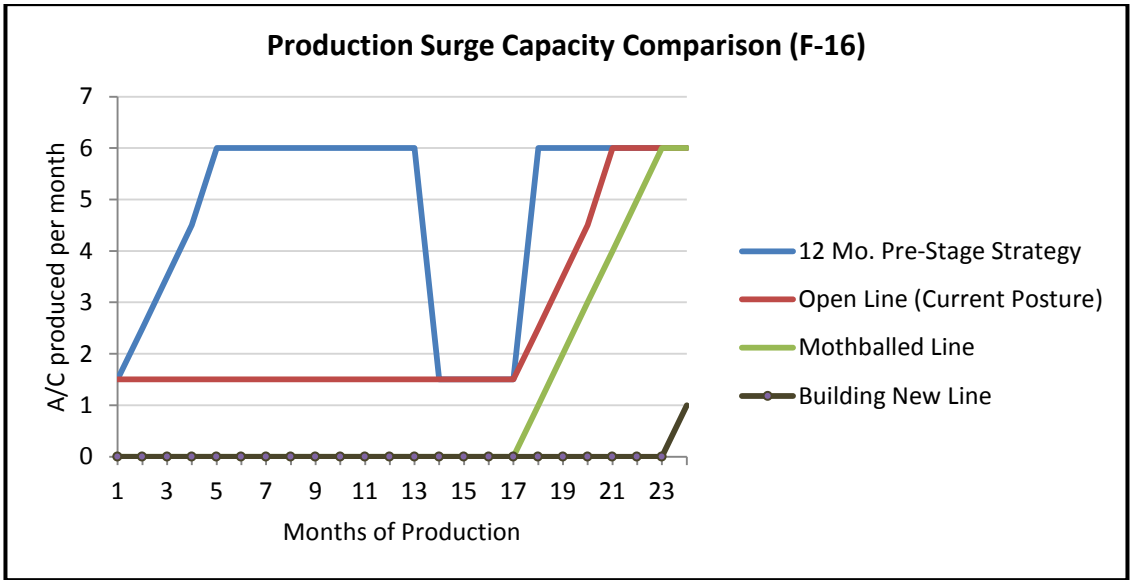


Figure 21. Production surge capacity comparison for F-16

The advantage of a 12-month pre-staging strategy of critical long lead components on an open line is striking. In this scenario, the line could expand by one fighter per month after the first month and reach the max tooling capacity of six fighters during the fifth month. Considering the 12-months of pre-staged long lead items, the line could continue to produce to capacity for an additional eight months, until the pre-staged material is exhausted. The line then has to wait four months for the normal lead-time to catch up and supply more material. Once the lead-time catches up, the line can produce its max capacity of six fighters within one month because all pieces were previously in place for the additional capacity.

The key takeaway from Figure 21 is that in order to maximize surge capability, production lines of critical aircraft not only have to remain open, but also require pre-staged long lead items in order to execute an effective surge to support DoD in any future conflict. If such production facilities are mothballed or sold, then no surge potential exists for a minimum of 18 months and perhaps even longer.

9. CONSIDERATIONS FOR U.S. GOVERNMENT

Key Concerns for the U.S. Defense Aircraft Industry

Table 10. Summary of Key Concerns for the U.S. Aircraft Industry

Concern	Additional Considerations & Impact
Uncertainty in budget magnitude and budget priorities induces firm behavior that is adverse to national needs	• Firms are inherently conservative • Firms need good business case for R&D • Innovation is reduced because uncertainty drives conservative, incremental internal R&D • Cost increases due to uncertain production quantity
Lack of clear industrial and acquisition policy with clear priorities	• Industry responds to Gov decisions and requirements • Firms adopt "wait and see" strategies • Industrial base considerations not reflected in acquisition plans
Impact of JSF industrial model on procurement and sustainment	• Reduces competition • New MRO paradigms & risks • Erodes foreign policy and strategic partnering options via loss of high/low mix • Creates single-point ops and maintenance vulnerabilities • Precedent for future programs (FVL, LRS-B)
Consolidating/shrinking of domestic defense supply chain	• Defense is no longer largest customer • Decreasing defense budgets/programs and international supply sources increases competition for U.S. firms • Primes "squeezing" or acquiring subs • Reduces domestic capacity and innovation
Ability of industrial base to support large-scale protracted operations	• Lack of Gov policy/strategy to address large scale mobilization and surge capacity
Challenges in understanding extent of technology diffusion and assessing our comparative technological advantage	• Difficult to assess impacts of tech diffusion from foreign sales, offsets and IP theft • Hurts our ability to make targeted resource investments in specific technologies to maintain advantage
"Muddle through" industrial & resourcing strategy of the past may not work in emerging	• Potential severe implications on aircraft industrial base given the current industry state and trends • May cause increased M&A and firms to exit market

Considerations for U.S. Government

Given the concerns summarized above, the U.S. government should consider developing a deliberate and clearly communicated defense industrial strategy. Figure 22 depicts a general framework and is intended as a notional example of a strategy development roadmap. Although the analysis presented to this point has related to the aircraft industry, the following discussion can be generically applied to all sectors of the defense industry. Specific principles and actions might differ from those presented, but the benefit of applying a framework such as this is in coherent strategy development that is based on an assessment of the environment and identification of guiding principles. The developed strategy can then be used to make decisions on trade-offs or difficult issues that may impact the industrial base.

Environment assessment. Strategy begins with a diagnosis of the problem, which consists of assessing key factors, including: national interests, threat environment, nature of the international competitive business environment, market forecasts and interactions, and domestic firm interests. An assessment of the environment is the foundation and global security context for which an industrial strategy relevant to national security interests can be developed.

Guiding principles. Guiding principles are conditions or value based behaviors that should be preserved in order to successfully implement the overall strategy. Clearly stating guiding principles on which an industrial strategy is founded forces debate on issues central to fostering the development of a consistent and sound government policy. Hallmark principles of historic U.S. industrial policy such as private firms, free markets, and the importance of competition could form the core of guiding principles for industrial strategy.

Coherent action. In an era of constrained resources, prioritization of investments will be crucial to ensure that technological advantage is maintained in key areas. As a result, the first step in developing a coherent action plan is to establish a prioritized list of core-competencies. The identification of coherent actions will rest on defense capability and capacity needs which will drive the development of defense industrial base core competencies.

Once core competencies are identified, specific industries and industry segments must be examined to determine what kind of market structure is supportable. A competitive free market is the ideal, and specific actions noted in the framework may help preserve competition. In segments or industries where competition is no longer viable different rules should be applied to preserve necessary capabilities. In some cases a division of competencies between government arsenals and private firms could be established. Further, government could protect key capabilities by requiring selection of specific lower tier supply sources or more strongly define firm internal R&D requirements. Lastly, a defense industrial strategy must encompass a research and development strategy, an export strategy/policy, and business environment rules and conditions for which industry must operate.

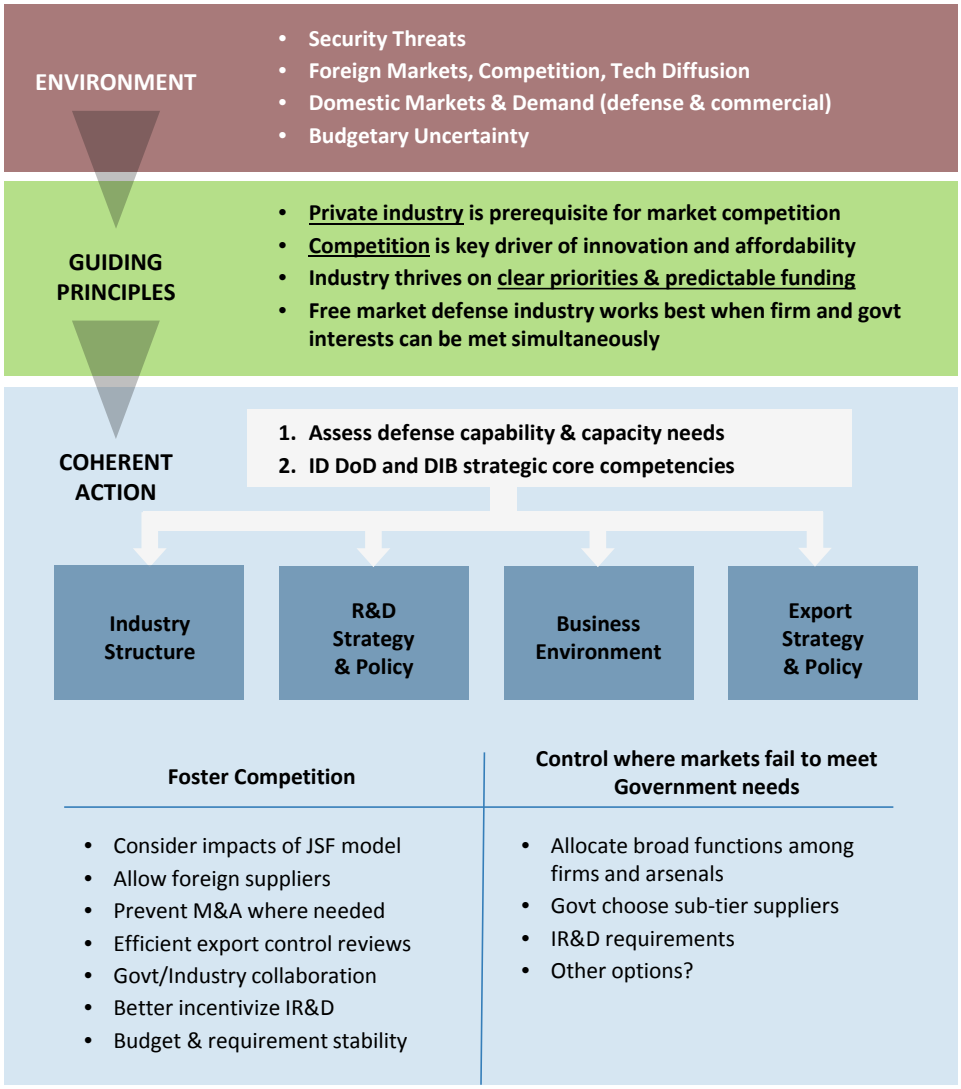


Figure 22. Framework for developing a Defense Industrial Strategy

General recommendations. As firms in the defense aircraft industry make strategic decisions in light of the recent downturn in government spending, the choices made may not always align with the interests of the government in preserving the necessary industrial capability and capacity. For instance, a firm's decision to exit a market may result in a monopolistic market that is clearly not preferable for future competitions to meet government requirements. In general, the possible range of government actions should seek to restore domestic competitiveness, improve technological dominance, enhance affordability, and achieve exportability of aircraft sufficient to meet foreign policy needs. As noted, the structure of the

industry responds over the long term to government requirements. While the full range of possible actions are too numerous to effectively list here (and are situation dependent), key examples are offered that address the negative consequences of existing trends and may prove useful for consideration and stimulation of further analysis.

- Increase frequency of competition while emphasizing schedule
- Reduce requirement complexity and emphasize affordability over innovation in areas with existing technological dominance
- Consider a wider use of dual-use and globally supplied commercial technologies in defense platforms and equipment
- Prioritizing R&D investment in a set key technologies that will facilitate tech dominance in critical sectors of national defense
- Improve government to business communications to reduce uncertainty
- Improve efficiency of government export control reviews
- Reduce the use of large, common platform buys with single prime contractors in markets where competitiveness is threatened

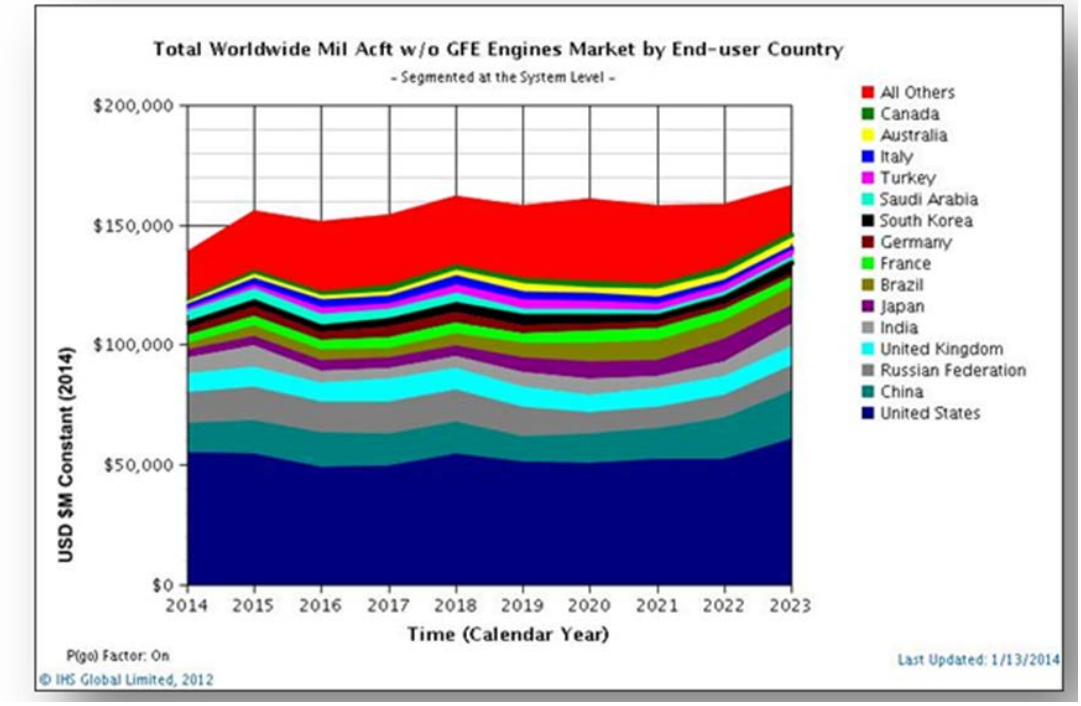
10. CONCLUSION

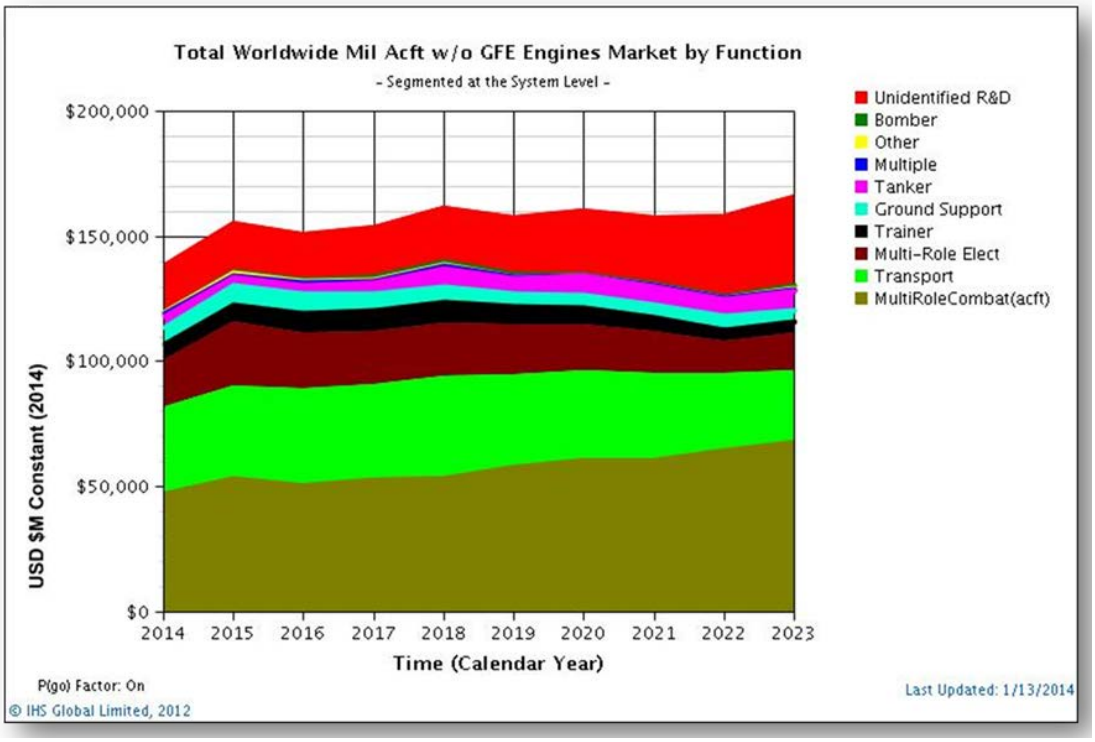
Ultimately, the national security of the U.S. is of interest to both government and industry. The defense aircraft industry is arguably a leading provider of both security and economic prosperity for the U.S., and policies that support competition as a way to achieve technological superiority at affordable prices have proven their worth over the course of the nation's history. Analysis of the structure of the domestic defense aircraft industry shows it supports these goals. While current trends point to some difficult times ahead in certain markets, overall, the industry appears poised to provide the systems the nation needs to meet current requirements while developing new innovations for the future.

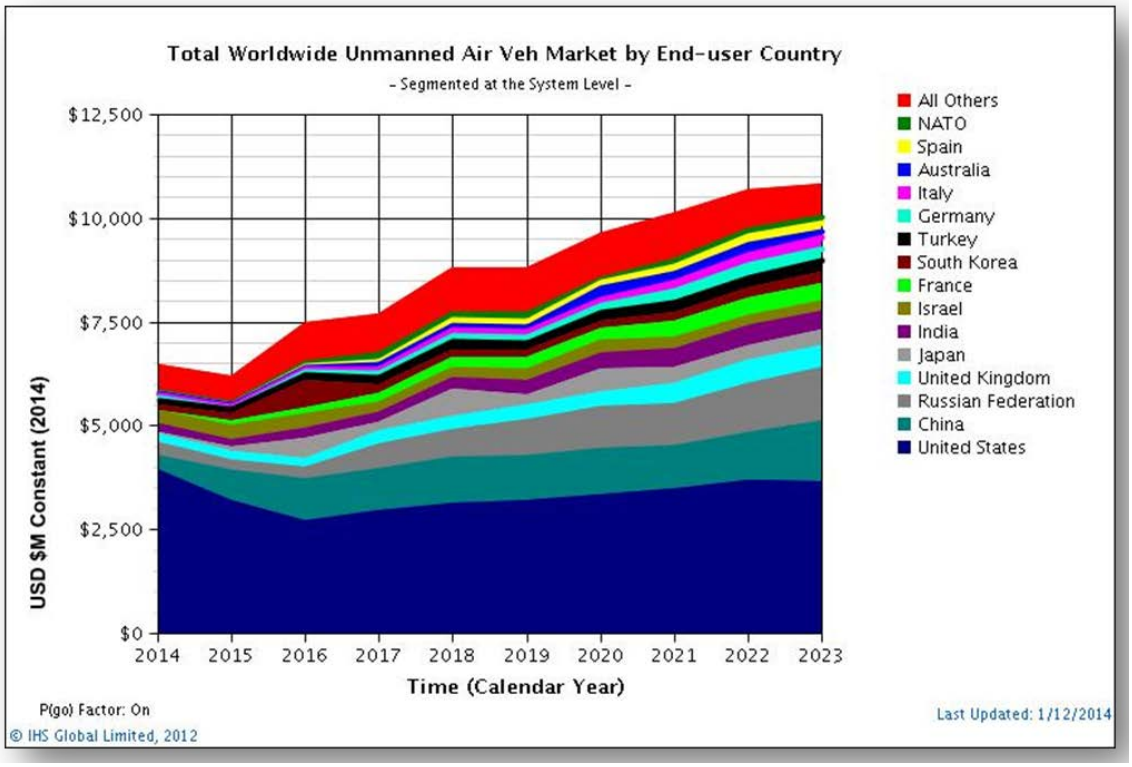
With careful assessment of firm strategic responses to the funding environment and near term programs, government can succeed in positively adjusting to unfavorable developments with the tools at hand. But simply continuing to issue new program requirements that appear to meet government needs without consideration of the impact to industry will likely result in potentially unrecoverable negative consequences for firms in critical markets such as fighters, bombers, and rotorcraft.

11. APPENDIX A

Total global projections of manned and unmanned aircraft markets.[228]






Total Worldwide Unmanned Air Veh Market by End-user Country
- Segmented at the System Level -
$12,500
$10,000
$7,500
$5,000
$2,500
$0
USD $M Constant (2014)
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
Time (Calendar Year)
All Others
NATO
Spain
Australia
Italy
Germany
Turkey
South Korea
France
Israel
India
Japan
United Kingdom
Russian Federation
China
United States
P(go) Factor: On
Last Updated: 1/12/2014
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Endnotes

[1] See, for example, John Birkler, et. al., *Keeping a Competitive U.S. Military Aircraft Industry Aloft* (Washington, D.C.: RAND, 2011).

[2] Barack Obama, *National Security Strategy* (Washington, DC: The White House, May 2010), 17.

[3] Chuck Hagel, *Quadrennial Defense Review 2014* (Washington, D.C.: Department of Defense, 2014), v.

[4] Jane's IHS, "U.S. DoD FY15 Budget Analysis," April 3, 2014, https://janes-ihs-com.nduezproxy.idm.oclc.org/ExternalItems/Janes/images/hybrid/jibr/jibr2013/data/jibr1060_a.pptx (accessed April 26, 2014), 15.

[5] Aerospace Industries Association, *2013 Year-End Review and Forecast* (Arlington, VA: Aerospace Industries Association, 2014), 4, http://www.aia-aerospace.org/assets/2013_AIA_Annual_report_webversion.pdf (accessed April 21, 2014).

[6] Ibid, 5.

[7] Sam Perlo-Freeman and Pieter D. Wezeman, *The SIPRI Top 100 Arms-Producing and Military Services Companies, 2012* (Solna, Sweden: Stockholm International Peace Research Institute, January 2014), 3, http://books.sipri.org/files/FS/SIPRIFS1401.pdf (accessed April 21, 2014).

[8] Jane's IHS, "U.S. DoD FY15 Budget Analysis," 32 & 37.

[9] Ibid, 23.

[10] Office of Management and Budget,"Table 5.1—Budget Authority by Function and Subfunction: 1976-2019," linked from *Historical Tables*, http://www.whitehouse.gov/omb/budget/historicals (accessed April 23, 2014).

[11] Jane's IHS, U.S. DoD FY15 Budget Analysis, 37.

[12] Ibid, 32.

[13] Ibid, 23.

[14] Marcus Weisgerber, "Weapons Spending Inches Upward," *DefenseNews*, March 31, 2014, http://www.defensenews.com/interactive/article/20140330/DEFREG02/303300013/Weapons-Spending-Inches-Upward (accessed April 23, 2014).

[15] Thomas L. McNaugher, *New Weapons, Old Politics: America's Military Procurement Muddle* (Washington, DC: The Brookings Institution, 1989), 21.

[16] McNaugher, *New Weapons*, 30.

[17] Mark Lorell, *The U.S. Combat Aircraft Industry 1909-2000, Structure, Innovation, Competition* (Santa Monica, CA: RAND, 2003), 112.

[18] Ibid, 115.

[19] Lockheed Martin Corporation, "2013 Annual Report," http://www.lockheedmartin.com/content/dam/lockheed/data/corporate/documents/2013-Annual-Report.pdf (accessed April 26, 2014), 3.

[20] Jane's IHS, "U.S. DoD FY15 Budget Analysis," 19.

[21] Hagel, *Quadrennial Defense Review*, v.

[22] Keving Dehoff, John Dowdy, and John Niehaus, *Managing a downturn: How the U.S. defense industry can learn from its past* (New York: McKinsey and Company, 2013), 5.

[23] Keith Krause, *Arms and the State: Patterns of Military Production and Trade*," Cambridge University Press, Cambridge, 1995, 212.

[24] Spear, "Defence Offsets: A System-Level View," 431.

[25] Ibid.

[26] Spear, "Defence Offsets: A System-Level View, 431

[27] Ibid.

[28] Aaron Mehta, "New USAF Training Head: T-X Requirements Under Review," *DefenseNews*, December 17, 2013, http://www.defensenews.com/article/20131217/DEFREG02/312170013/New-USAF-Training-Head-T-X-Requirements-Under-Review (accessed April 26, 2014).

[29] Ibid.

[30] Under terms of the meetings, discussions were held on a non-attribution basis and use of remarks made is only done when they can't be associated with any one company. Meetings were held during the period of January to April 2014.

[31] Mark Arena and Kevin Brancato, *Why Has the Cost of Fixed-Wing Aircraft Risen?* (Santa Monica, CA: RAND Corporation, 2008), 58.

[32] Ibid., 62.

[33] Ibid., 64.

[34] Mark Arena, et. al., *A Macroscopic Examination of the Trends in U.S. Military Aircraft Costs over the Past Several Decades* (Santa Monica, CA: RAND, 2008), 11.

[35] Russell Rumbaugh, *What We Bought: Defense Procurement from FY01 to FY10* (Washington, DC: Henry L. Stimson Center, Oct 2011), 24.

[36] Richard Aboulafia, "Aircraft Markets in an Age of Extremes", presentation to Eisenhower School Aircraft Industry Study in February, 2014, slide 32.

[37] Arena, et. al., *A Macroscopic Examination*, 79-80.

[38] Ibid, 79.

[39] Daniel Nicholas Marticello Jr., *Complexity Within the Air Force Acquisition System: Gaining Insight from a Theory of Collapse* (Cambridge: Massachusetts Institute of Technology, February, 2012), 31.

[40] Government Accountability Office, "F-35 Joint Strike Fighter: Current Outlook Is Improved, but Long-Term Affordability Is a Major Concern," March, 2013, 5.

[41] James C. Ruehrmund, Jr. and Christopher J. Bowie, *Arsenal of Airpower: USAF Aircraft Inventory, 1950-2009* (Arlington, VA: Mitchell Institute Press, 2010), 8, http://higherlogicdownload.s3.amazonaws.com/AFA/6379b747-7730-4f82-9b45-a1c80d6c8fdb/UploadedImages/Mitchell%20Publications/Arsenal%20of%20Airpower.pdf (accessed April 26, 2014).

[42] Birkler, et. al., *Keeping a Competitive…*, 22.

[43] Marticello, *Complexity Within…*, 83.

[44] Richard Aboulafia, "Market Overview: Fighter/attack aircraft," The Teal Group, February, 2014.

[45] James Fallows, "Uncle Sam Buys an Airplane," *The Atlantic Monthly*, June, 2002.

[46] Rumbaugh, "What We Bought: Defense Procurement from FY01 to FY10."

[47] James Fallows, "Uncle Sam Buys an Airplane," *The Atlantic Monthly*, June, 2002.

[48] Mark A. Lorell, et. al., *The Department of Defense Should Avoid a Joint Acquisition Approach to the Sixth-Generation Fighter*, (Santa Monica, CA: RAND Corporation, 2013).

[49] Mark Lorell and Michael Kennedy, *Do Joint Fighter Programs Save Money* (Santa Monica, RAND Corporation, 2013).

[50] Lorell, et. al., *The Department of Defense Should Avoid…*

[51] Andrea Shalal-Esa, "Insight: Lockheed's F-35 logistics system revolutionary but risky," Reuters, November 16, 2012.

[52] John Stillion and Scott Perdue, "Air Combat Past, Present and Future," RAND Corporation briefing slides, August, 2008.

[53] Mark A. Gunzinger and David A. Deptula, "Toward a Balanced Combat Air Force," Center for Strategic and Budgetary Assessments, 2014, 12.

[54] Tony Capaccio, "Gates Says Israel Gave In on Saudi Arms After F-35 Pledge," Bloomberg, January 9, 2014.

[55] Lorell, et. al., *The Department of Defense Should Avoid…*

[56] Caitlin Lee, "AUSA 2013: Army to downselect to two JMR-TD bidders in 2014," *IHS Jane's 360*, October 21, 2013, http://www.janes.com/article/28556/ausa-2013-army-to-downselect-to-two-jmr-td-bidders-in-2014 (accessed April 26, 2014).

[57] Michael E. Porter, *Competitive Advantage: Creating and Sustaining Superior Performance* (New York: The Free Press, 1985) as summarized by QuickMBA, "Competitive Advantage," www.quickmba.com/strategy/competitive-advantage (accessed May 14, 2014).

[58] Ibid.

[59] Ibid.

[60] Lockheed Martin Corporation, "2013 Annual Report," 24.

[61] Office of the Deputy Assistant Secretary of Defense for Manufacturing and Industrial Base Policy, "Annual Industrial Capabilities Report to Congress," October, 2013, http://www.acq.osd.mil/mibp/docs/annual_ind_cap_rpt_to_congress-2013.pdf (accessed April 26, 2014), 1.

[62] Ibid.

[63] John Birkler, et. al., *Competition and Innovation in the U.S. Fixed-Wing Military Aircraft Industry* (Santa Monica, CA: RAND, 2003), 56.

[64] Ibid.

[65] Ibid.

[66] George R. Hall and R. E. Johnson, *Transfers of United States Aerospace Technology to Japan*, (Santa Monica, CA: RAND Corporation, 1968), 5.

[67] Lorell, *The U.S. Combat Aircraft Industry*, 9.

[68] Ibid., 54.

[69] Ibid., 51.

[70] Ibid., 89.

[71] Ibid., 13.

[72] Ibid., 131.

[73] Data from the Mitchell Institute for Airpower Studies, Air Force Association.

[74] Joe Pappalardo, "PM Interview: Air Force Gen. Mark A. Welsh III," *Popular Mechanics*, 15 Apr, 2014.

[75] Jeremiah Gertler, "Air Force F-22 Fighter Program," Congressional Research Service, July 11, 2013, 4.

[76] M. Thomas Davis and David Barno, "The Enduring Need for Electronic Attack in Air Operations," *Policy Brief*, Center for New American Security, Jan 2014, 4.

[77] "Joint Operational Access Concept," U.S. Department of Defense, Jan 2012, ii.

[78] "Systems Engineering Guide for Systems of Systems," Office of the Under Secretary of Defense, Version 1.0, Aug 2008, 11.

[79] "Joint Operational Access Concept," U.S. Department of Defense, Jan 2012, 34.

[80] Marc V. Schanz, "ISR After Afghanistan," *Air Force Magazine*, Vol. 96, No. 1.

[81] Mark A. Gunzinger and David A. Deptula, *Toward a Balanced Combat Air Force* (Washinton, DC: Center for Strategic and Budgetary Assessments, 2014), 14.

[82] Robbin Laird and David Deptula "Shaping the Way Ahead for Airpower: General Hostage Focuses on the Future," interview hosted by *Second Line of Defense*, Dec 2012.

[83] Based on interviews with selected industry firms, April, 2014.

[84] Data from Mark Lorell and Hugh Levaux, *The Cutting Edge, A Half Century of U.S. Fighter Aircraft R&D* (Washington, DC: RAND Corporation, 1998).

[85] Richard Aboulafia, "Market Overview: Fighter/attack Aircraft," The Teal Group, February, 2014.

[86] Sam Brothers and Joshua Archer, "How Dependent are East Asian States on Arms Imports?," *Current*, Issue No. 35, Center for Strategic and International Studies, October 15, 2013.

[87] Aboulafia, "Market Overview: Fighter/attack Aircraft."

[88] Aaron Mehta and Wendell Minnick, "F-16 Upgrade Dropped From US Budget Proposal Sources Say," *DefenseNews*, http://www.defensenews.com/article/20140127/DEFREG/301270023/F-16-Upgrade-Dropped-From-US-Budget-Proposal-Sources-Say, January 27, 2014.

[89] Andrea Shalal-Esa, "BAE finalizes South Korean F-16 upgrade deal, eyes more prospects," *Reuters*, December 23, 2013.

[90] Brendan McGrarry, "BAE Adds F-15, F/A-18 to Fighter Upgrade Push," *DoD BUZZ*, February 14, 2014, http://www.dodbuzz.com/2014/02/14/bae-adds-f-15-fa-18-to-fighter-upgrade-push/ (accessed May 19, 2014).

[91] Based on interviews with selected industry firms, April, 2014.

[92] Ibid.

[93] Ibid.

[94] Kate Brannen, "2015 budget preview – Army-Guard fight gets ugly – OSD turns down Navy request to take a 'break' from F-35," *Politico*, February 3, 2014.

[95] Based on interviews with selected industry firms, April, 2014.

[96] Roxana Tiron, "Money Fights That Could Shape 2015 Defense Bills—Part 1," *Bloomberg*, April 08, 2014.

[97] Joel B. DuBow, "Defense Planning: Managing Market Contraction," *Defense Analysis*, Volume 9, Issue 3, 1993.

[98] Graphical depiction of trends described in Mark Lorell and Hugh Levaux, *The Cutting Edge*, 158.

[99] "World Unmanned Aerial Vehicle Systems," Teal Group, 2013.

[100] Keith Hayward, *Unmanned Aerial Vehicles: A New Industrial System?* (London: Royal Aeronautical Society, October, 2013), http://aerosociety.com/Assets/Docs/Publications/DiscussionPapers/UASDiscussionPaper.pdf (accessed MAy 19, 2014).

[101] "2013 Worldwide UAV Round-Up," *Aerospace America* Supplement, July/Aug 2013 edition, Aerospace Institute of Aeronautics and Astronautics, http://www.aerospaceamerica.org/Documents/AerospaceAmerica-PDFs-2013/July-August-2013/2013_UAV%20Chart.pdf (accessed May 19, 2014).

[102] Ibid.

[103] Stanley Carvalho, "UAE signs $1.4 billion defense contracts, including drones," February 14, 2013 http://www.reuters.com/article/2013/02/18/us-emirates-drones-idUSBRE91H0AY20130218 (accessed May 19, 2014).

[104] Keith Hayward, *Unmanned Aerial Vehicles: A New Industrial System?* (London: Royal Aeronautical Society, October, 2013), http://aerosociety.com/Assets/Docs/Publications/DiscussionPapers/UASDiscussionPaper.pdf (accessed MAy 19, 2014).

[105] Burak Ege Bekdil, "Turkish Company Hopes To Build New Anka Engine, Win Exports," *Defense news*, April 12, 2014.

[106] Hayward, *Unmanned Aerial Vehicles*.

[107] Jane's Defence Weekly, Briefing: The unmanned race gathers pace, May 01, 2013

[108] "UAV Round-Up," Aerospace America, July/Aug 2013 edition.

[109] Lynne E. Davis, et. al., Armed and Dangerous? UAVs and U.S. Security (Santa Monica, CA: RAND, 2014), http://www.rand.org/pubs/research_reports/RR449.html (accessed May 19, 2014).

[110] Guy Anderson, "South America's Defence Industrial Rebirth Strategies, Drivers, Capabilities and Implications for the Global Markets," IHS Jane's Defence Industry, August 2, 2012.

[111] John Dowdy and Melanie Taylor, "Defense Outlook 2015: A Global Survey of Defense Industry Executives," McKinsey and Company, April 2013.

[112] Glennon Harrison, *Challenge to the Boeing-Airbus Duopoly in Civil Aircraft: Issues for Competitiveness*, (Washington, DC: Congressional Research Service, July 25, 2011).

[113] Keith Crane, et. al., *The Effectiveness of China's Industrial Policies in Commercial Aviation Manufacturing*, (Santa Monica, CA: RAND 2014).

[114] Ibid, xiv.

[115] Industry executive briefing slides, February 20, 2014.

[116] Richard Aboulafia, the Teal Group, presentation to Eisenhower School, February, 2014.

[117] The Boeing Company SEC Form 10K, 2014, page 19.

[118] Airbus, *Future Journeys: Global Market Forecast, 2013-2032*, http://www.airbus.com/company/market/forecast/?eID=dam_frontend_push&docID=33752 (accessed May 19, 2014).

[119] Andreas Knorr, "Subsidies in Civil Aircraft Manufacturing: The World Trade Organization (WTO) and the Boeing-Airbus Dispute WTO findings," *European State Aid Law Quarterly*, Vol 3, 2012.

[120] Boeing Corporation, *Current Market Outlook 2013-2032*, 2013, http://www.boeing.com/assets/pdf/commercial/cmo/pdf/Boeing_Current_Market_Outlook_2013.pdf (accessed MAy 19, 2014), 4.

[121] Airbus *Future Journeys*,, 14-15.

[122] Airbus *Future Journeys*, 14.

[123] Boeing *Current Market Outlook*, 15.

[124] Based on interviews with selected industry firms, April, 2014.

[125] Craig Hoyle, "Airbus Confirms Singapore Tanker Deal Signed," *FlightGlobal*, March 7, 2014, http://www.flightglobal.com/news/articles/airbus-confirms-singapore-tanker-deal-signed-396752/ (accessed May 19, 2014).

[126] Dominic Perry, "India selects Airbus Military MRTT for six-aircraft deal," *FlightGlobal*, January 7, 2013, http://www.flightglobal.com/news/articles/india-selects-airbus-military-mrtt-for-six-aircraft-380740/ (accessed May 19, 2014).

[127] Pierre Trn, "French AF To Take 2 MRTT Versions," *Defense News*, February 21, 2014, http://www.defensenews.com/article/20140221/DEFREG01/302210021/French-AF-Take-2-MRTT-Versions (accessed May 19, 2014).

[128] Airbus press release, "Qatar Selects Airbus A330 MRTT Multi Role Tanker Transport," http://www.a330mrtt.com/PressCenter/LatestNews/TabId/176/ArtMID/681/ArticleID/317/Qatar-selects-Airbus-A330-MRTT-Multi-Role-Tanker-Transport.aspx (accessed April 24, 2014).

[129] Domenic Gates"Boeing celebrates 787 delivery as program's costs top $32 billion," *The Seattle Times*, September 25, 2011.

[130] Richard Aboulafia, *March 2014 Letter*, www.Richardaboulafia.com, 28 March 2014.

[131] Kevin Michaels, *MRO Market Forecast & Industry Dynamics*. Aviation Week MRO Americas 2013, Atlanta, GA, Slide 14.

[132] Ibid, slide 15.

[133] Airbus, *Future Journeys*, 29.

[134] Boeing *Current Market Outlook*, 18.

[135] Embraer website, http://www.embraerds.com/english/content/cargo/overview.asp, 23 Apr 2014 (accessed May 19, 2014).

[136] Based on interviews with selected industry firms, April, 2014.

[137] Pam Valdez *KC-46 Sustainment*. Aviation Week Maintenance Repair & Overhaul Conference, April 5, 2012, Slide 13.

[138] Based on interviews with selected industry firms, April, 2014.

[139] Department of the Air Force, . *Update on KC-46A and Legacy Aerial Refueling Aircraft Programs* , Presentation to the House Armed Services Committee, Subcommittee on Seapower and Projection Forces, U.S. House of Representatives, 13 Oct 2011.

[140] Boeing website, http://www.boeing.com/boeing/defense-space/military/kc46a (accessed 22 Apr 2014).

[141] Robbin Laird, "Shaping a Defense Quadrangle for Pacific Defense: Allies Shape a Flying Air Tanker Infrastructure," Second line of Defense, December 3, 2103, www.sldinfo.com/shaping-a-defense-quadrangle-for-pacific-defense-allies-shape-a-flying-air-tanker-infrastructure (accessed May 19, 2014).

[142] Bill Carey, "Paris 2011 Hardcopy: P-8 Production Advances; JSTARS replacement Eyed," June 20, 2011, http://www.ainonline.com/aviation-news/paris-air-show/2011-06-20/paris-2011-p-8-production-advances-jstars-replacement-eyed (accessed May 19, 2014).

[143] Ibid.

[144] Mark A. Gunzinger, "Sustaining America's Strategic Advantage in Long-Range Strike," CSBA, 2010.

[145] Mark A. Gunzinger and David A. Deptula, Toward a Balanced Combat Air Force (Washinton, DC: Center for Strategic and Budgetary Assessments, 2014).

[146] IHS Janes, "Helicopter Markets," January 20, 2014.

[147]Richard Aboulafia, "Aircraft Markets in an Age of Extremes", presentation to Eisenhower School Aircraft Industry Study in February, 2014, slide 44.

[148] IHS Janes, "Helicopter Markets," January 20, 2014

[149] Richard Aboulafia, slide 43.

[150] Ibid.

[151] Ibid, slide 42.

[152] "DoD Needs Industrial Strategy," DefenseNews editorial, March 30, 2014, http://www.defensenews.com/article/20140330/DEFREG02/303300018/Editorial-DoD-Needs-Industrial-Strategy (accessed May 19, 2014).

[153] IHS Janes, "Helicopter Markets," January 20, 2014.

[154] Ibid.

[155] Ibid.

[156] Malenic Marina, "Bell stops work on Kiowa upgrade," *Jane's Defence Weekly*, (May 5, 2014).

[157] Ibid.

[158] IHS Janes, "Helicopter Markets," January 20, 2014.

[159] "DoD Needs Industrial Strategy," *DefenseNews* editorial, March 30, 2014.

[160] IHS Janes, "Helicopter Markets," January 20, 2014.

[161] AirlineUpdate.com, http://www.airlineupdate.com/content_subscription/mro/northamerica/usa_bg.htm (accessed January 21, 2014).

[162] James Crompton, *IBIS World Industry Report 48819, Aircraft Maintenance, Repair & Overhaul in the US* , December 2013, 20.

[163] Ibid.

[164] James Crompton, *IBIS World Industry Report 48819, Aircraft Maintenance, Repair & Overhaul in the US* , December 2013, 20.

[165] Ibid.

[166]Daniel Wasserbly, "Boeing offering 80 CH-47Ds to international market," *Jane's Defence Weekly* (March 27, 2014).

[167] Aeroweb, "Aerospace Sector, GE," http://www.bga-aeroweb.com/General-Electric.html (accessed April 2, 2014).

[168] GE Website, "GE Aviation and HNA Group To Form MRO Joint Venture for GE's CF34-10 Engines," http://www.geaviation.com/press/services/services_20101116.html, November 16, 2010, (accessed April 2, 2014).

[169] Richard Aboulafia, "Lockheed Martin F-35 Joint Strike Fighter, World Military and Civilian Aircraft," Teal Group, March 2014.

[170] James Crompton, *IBIS World Industry Report 48819, Aircraft Maintenance, Repair & Overhaul in the US* , December 2013, 26.

[171] Ibid.

[172] Ibid, 28.

[173] Based on interviews with selected industry firms, April, 2014.

[174] Based on interviews with selected industry firms, April, 2014.

[175] Based on interviews with selected industry firms, April, 2014.

[176] Based on interviews with selected industry firms, April, 2014.

[177] James Crompton, *IBIS World Industry Report 48819, Aircraft Maintenance, Repair & Overhaul in the US* , December 2013, 20.

[178] Based on interviews with selected industry firms, April, 2014.

[179] Hollis Hunter, "It's the Law, Title 10 for Maintainers (Depot Focus)," presentation to DoD Maintenance Symposium, October 28, 2002, http://www.sae.org/events/dod/presentations/hollis-hunter.pdf (accessed May 19, 2014).

[180] Based on interviews with selected industry firms, April, 2014.

[181] Ibid.

[182] Ibid.

[183] Michael Howard, "Military Aircraft MRO Forecast," ICF International, April 8, 2014, 7-9.

[184] Ibid, 10-13.

[185] Ibid, 14, 15.

[186] Rene Ouimet and Bob Willen, "The Next Last Supper: New Dynamics Drive A&D Industry Changes," *DefenseNews*, Aug 4, 2013, http://www.defensenews.com/article/20130804/DEFREG02/308040010/The-Next-Last-Supper-New-Dynamics-Drive-D-Industry-Changes.

[187] James Crompton, *IBIS World Industry Report 48819, Aircraft Maintenance, Repair & Overhaul in the US*, December 2013, 10.

[188] Gunzinger and Deptula, "Toward a Balanced Combat Air Force," 2.

[189] Jonathan Berger, "MRO Market Forecast and Industry Dynamics," ICF International brief, October 2013.

[190]Richard Aboulafia, "Lockheed Martin JSF Joint Strike Fighter," World Military and Civilian Aircraft, Teal Group, March 2014, 11-13.

[191] Brad Curren, "Global Defense Outlook: Equipment and Services Opportunities," briefing slides, Frost and Sullivan, April 2014, 5.

[192] IHS Janes, "Defence Market Forecasts: Looking Ahead to 2014 and Beyond," 2012, 2.

[193] Ibid. 27.

[194] Brad Curren, "Global Defense Outlook…," 25.

[195] Ben Moores & Paul Burton, "A Balance of Trade: An Evolving Global Defense Market," IHS Janes, June 2013, 3.

[196] Ibid, 5.

[197] Frost and Sullivan, "US DoD Foreign Military Sales: Defense Budget Cuts Driving Foreign Sales Focus," March 2013, 8.

[198] U.S. Department of Commerce Bureau of Industry and Security, *Offset in the Defense Trade Eighteenth Study,* (Washington, DC: U.S. Department of Commerce, December 2013), 10.

[199] Frost and Sullivan, "US DoD Foreign Military Sales…," 33.

[200] Christopher Lane and Robert Metzger, "Reforming Post-Cold War U.S. Arms Sales Policy: the Crucial Link between Exports and the Defense Industrial Base," *The Journal of Strategic Studies*, Vol 18, No 4 (December 1995): 2-3.

[201] Frost and Sullivan, "US DoD Foreign Military Sales…," 14.

[202] Office of the Press Secretary, "President Obama Lays the Foundation for a New Export Control System To Strengthen National Security and the Competitiveness of Key U.S. Manufacturing and Technology Sectors," The White House, August 30, 2010, http://www.whitehouse.gov/the-press-office/2010/08/30/president-obama-lays-foundation-a-new-export-control-system-strengthen-n (accessed March 20, 2014).

[203] Ibid.

[204] Remarks of Eric L. Hirschhorn Under Secretary for Industry and Security at the Society for International Affairs Fall Conference October 28, 2013, http://www.bis.doc.gov/index.php/about-bis/newsroom/speeches/47-about-bis/newsroom/591-

remarks-of-eric-l-hirschhorn-under-secretary-for-industry-and-security-society-for-international-affairs-fall-conference-october-28-2013 (accessed April 5, 2014).

[205] Ibid.

[206] Ibid.

[207] Conference Report, *The EU defense market: balancing effectiveness with responsibility,* Flemish Peace Institute, September 2011.

[208] Joanna Spear, "Defence Offsets: A System-Level View", *Strategic Analysis*, vol. 37, no. 4, (2013): 430.

[209] U.S. Department of Commerce Bureau of Industry and Security, *Offset in the Defense Trade Eighteenth Study* (Washington, DC: U.S. Department of Commerce, December 2013), 1.

[210] Ibid., 10.

[211] Dominik Kimla, "Military Offsets & In-country Market Insight Top 20 Military Offset Market," briefing slides, Frost and Sullivan, March 2013, 9.

[212] Jurgen Brauer and Paul Dunne, "Arms Trade Offsets and Development," June 2005, Paper 504, http://carecon.org.uk/DPs/0504.pdf. 3-4.

[213] Christopher Lane and Robert Metzger, "Reforming Post-Cold War U.S. Arms Sales Policy: the Crucial Link between Exports and the Defense Industrial Base," *The Journal of Strategic Studies*, Vol 18, No 4 (December 1995): 6-7.

[214] Spear, "Defence Offsets: A System-Level View, 432-433.

[215] Guy Anderson and Brian de Marmels, *Defence Offset: The Major Trends Shaping Industrial Participation,* Online Video Briefing, (IHS Jane's, March 2014), www.ihs.com

[216] Ibid.

[217] Ibid, 11.

[218] Ibid, 12.

[219] Guy Anderson and Brian de Marmels, *Defence Offset: The Major Trends Shaping Industrial Participation,* (IHS Jane's, March 2014).

[220] Dominik Kimla, "Military Offsets & In-country Market Insight Top 20 Military Offset Market," 9.

[221] Ibid. 7.

[222] Dominik Kimla, "Military Offsets & In-country Market Insight Top 20 Military Offset Market," 31.

[223] Ibid. 32.

[224] Ibid. 25.

[225] Ibid. 26.

[226] John T. Williams, "Pros and Cons of the JIT Inventory System" *Demand Media,* http://smallbusiness.chron.com/pros-cons-jit-inventory-system-3195.html (accessed May 19, 2014).

[227] Based on interviews with selected industry firms, April, 2014.

[228] IHS Janes, "Defence Market Forecasts: Looking Ahead to 2014 and Beyond," 2012.