Spring 2011
Industry Study

Final Report
Aircraft Industry

The Industrial College of the Armed Forces
National Defense University
Fort McNair, Washington, D.C. 20319-5062

AIRCRAFT INDUSTRY STUDY 2011

ABSTRACT: Few national industries approach the aircraft industry in terms of strategic importance to national defense. In pursuit of national power, wealth, and technology development, the extent to which national policy can promote healthy competition and sustained innovation is of vital importance to senior policy makers. In order to frame this year's study, the industry group evaluated the domestic and international ramifications of the KC-X tanker program decision and the F-35 Joint Strike Fighter (JSF) program on the both industry and their respective markets. Due to their scale and estimated life cycle, the success or failure of these respective programs to meet objectives in terms of cost, schedule, and performance, will shape more than just military requirements and capability. These programs not only establish trends for future domestic production capacity, their execution underpins highly complex defense trade linkages and political alliances. Should these programs fail, when coupled with the current global trends of rapid growth in Asia, declining defense budgets in Europe, and financial uncertainty in the United States, the result would certainly force a reevaluation of national capacity to support the industry and hasten the entrance of new or more aggressive competition.

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Places Visited

Regional Visits

4 February	Aerospace Industries Association	Arlington, VA
11 February	Lockheed Martin	Crystal City, VA
24 February	Pratt & Whitney	Middletown, CT
25 February	Sikorsky	Stratford, CT
4 March	Aurora Flight Sciences	Manassas, VA
24 March	Boeing Rotorcraft	Philadelphia, PA
17 April	Finmeccanica North America	Washington, DC

Domestic Travel

4 April	Boeing	Everett, WA
5 April	Boeing	Renton, WA
6 April	General Atomics	Palmdale, CA
6 April	Northrop Grumman	Palmdale, CA
6 April	Lockheed Martin Skunk Works	Palmdale, CA
7 April	Bell Helicopter	Fort Worth, TX
8 April	Lockheed Martin Aeronautics	Fort Worth, TX

International Travel

2 May	Saab Aeronautics	Linköping, Sweden
3 May	Swedish Ministry of Defense	Stockholm, Sweden
3 May	Stockholm International Peace Research Institute (SIPRI)	Stockholm, Sweden
5 May	Airbus	Hamburg, Germany
6 May	Cassidian, European Aeronautic Defence and Space (EADS) Germany, Political Affairs	Berlin, Germany
6 May	United States Embassy	Berlin, Germany
9 May	EADS Corporate Headquarters	Paris, France
9 May	Institut des hautes études de défense nationale (IHEDN)	Paris, France
10 May	Groupement des Industries Françaises Aéronautiques et Spatiales (GIFAS)	Paris, France
12 May	SAFRAN	Paris, France

Introduction

The purpose of the Aircraft Industry Study (AIS) this year was to present the Department of Defense and, in particular, OSD/AT&L leadership with a thorough analysis of the current state of the aircraft industry to advise future decision-making in support of a healthy defense industrial base. The document's ultimate utility will be its relevance to policy-makers. The seminar focused on two essential questions for the aircraft industry in the U.S.:

1. What is the impact of the U.S. KC-X competition on the large commercial aircraft (LCA) market?

2. What is the impact of the F-35 Joint Strike Fighter program on the fighter aircraft market?

This paper explores the status of the LCA market, employing the structure, conduct, and performance (SCP) of the major competitors, and the likely effects and consequences of the recent USAF tanker procurement decision on the LCA market. In the strike fighter market, the seminar examined achieving value in the market, applied Porter's Five Forces in analyzing the market, and examined firm strategies. The paper examines the Joint Strike Fighter program and its implications on U.S. Government relationships with partners, management of its global supply chain, the impact of JSF on future competitiveness in the market, and concerns over the defense industrial base and preservation of critical aerospace engineering, design, and development skills.

The AIS took a keen interest in areas of high-technology competition, strategic trade and industrial policy issues in the LCA market. It also considered the evolution of newer entrants such as Embraer and Bombardier; especially insofar as this will eventually affect China and their own reemerging LCA industry. While the LCA market represents a *de facto* duopoly (Boeing and EADS have fairly healthy order books and are competing head to head in emerging markets), they are facing significant global challenges. The 787 and the A380 have both proven to be relatively successful, as have their workhorses—the B737 and the A320. The drivers examined include elements of their corporate behaviors and strategies focusing mainly on how rising inflation and growing budget deficits will impact their future choices. Additionally, according to a December 2010 study by Frost and Sullivan, global defense spending from 2010-2015 will total nearly $4.8 trillion, increasing only at a 3.2% compound annual growth rate. Furthermore, non-traditional markets in the Asia-Pacific, Middle East and North Africa, and South Central Asia regions will represent the majority of growth. Finally, defense procurement in the U.S. is assessed to remain relatively stable through 2015.[1]

The impact of the financial crisis continues to permeate and will in turn have substantial follow-on impacts for the aircraft industry. It is not all "blue skies", although emerging markets represent a type of panacea for both firms. A new type of global businesses environment is already acknowledged by several key administration officials. For example, the Secretary of Defense has openly stated that "defense manufacturing is a global business."[2] The USD for AT&L, Dr. Carter has gone even further by specifically noting that European products are "part of a global industrial base"[3], which deserves consideration; especially if these designs can be purchased at lower cost." The global defense industrial base is evolving rapidly.

The leading U.S. defense and aerospace companies are engaged in a fierce struggle for access and influence in foreign markets. The international focus of U.S. prime defense contractors grew significantly over the last several years. Stefan Zoeller, the head of Cassidian (EADS) has also stated: "European markets will decline…or be stable at best. Strategically, we have to go where the money is and the money is around the globe. The company has to generate growth to maintain our industrial base at home."[4]

The recent tanker decision taken by the United States Air Force (USAF) and DoD to select Boeing for the new generation of tankers will most likely influence future aircraft production and engineering cooperation. Although EADS did not win the competition, they have *de facto* demonstrated the capability to become a sixth major defense and aerospace contractor within the U.S. market. Furthermore, although EADS did not win the tanker competition, its presence in the competition resulted in significant cost savings to the U.S. taxpayer.

EADS demonstrated that competition drives efficiencies in the U.S. aircraft market. The major European defense and aerospace manufacturers have all targeted the U.S. market as their primary revenue growth market. For example, BAE Systems has successfully entered the U.S. market, where it derives most of its revenues.

On the other hand, the tanker decision may also prove to be anachronistic. It is hardly conceivable in the future the U.S. government will have the luxury and time to stretch out the decision-making process over a period of 30 years. Rather, persistent competition that includes manufacturers who are no longer considered "foreign" will be the norm. Nor will other bidders be so keen to just participate in a process with no clear prospects of a definable win. Furthermore, the tanker deal highlighted the divide in the United States between concerns that the American people are continuing to lose manufacturing jobs overseas and the desire to have a fair and open procurement process.

Regarding the second major question, the seminar perceives that the key element remains Lockheed Martin's ability to effectively manage a complex multinational program at a price affordable by today's defense budgets. With the promise of making a stealth strike fighter supportable and affordable, while also meeting the myriad technical demands for the services and multinational partners, the JSF program attempts to achieve what no other program has accomplished. Thus far, it has struggled to meet its programmatic requirements while also failing to deliver at the originally planned price. While program challenges in defense acquisition projects are not unusual, the pressures to successfully execute this multinational program during a period of global financial uncertainty and the transfer of wealth and power from the West to reemerging markets significantly raises the import of this program. Furthermore, in view of the recent decision by India to select a European aircraft for its next fighter program, defense trade linkages increasingly are demonstrating that potential buyers and allies prefer a true partnership over the "best deal" with a two-way exchange of technology.

The Large Commercial Aircraft Market and KC-X

The LCA market

The large aircraft industry has four key players: Boeing, Airbus, Embraer, and Bombardier. Table 1, Appendix 1, outlines their strategies, political environments, market preferences, financial state, and likely actions in the future. Embraer and Bombardier are on the edge of becoming larger players with introduction of larger single aisle aircraft over the next five to ten years.

Boeing and EADS/Airbus are pursuing diversification of their portfolios to balance the cyclical nature of the commercial aircraft market. Government contracts mitigate the cycles to some degree and winning government contracts are critical for financial stability over the long haul for these firms. Embraer and Bombardier are still somewhat limited in their scope and scale and have not yet aggressively pursued large defense contracts.

Another shared attribute among this group of competitors is adoption of a wide reaching global supply chain. Boeing has led this movement with their 787 program and provided many vicarious learning opportunities for its competitors in regard to managing the chain and the amount of effort needed to successfully take advantage of that mode of operation. It adds complexity, risk, and opportunity all at the same time and can complicate management's role of keeping cost, schedule, and performance under control. All key competitors appear to be consciously moving in this direction.

Boeing and Airbus effectively form a duopoly given Bombardier's much smaller footprint in the market. While Airbus currently surpasses Boeing in overall market value, the respective successes of the Boeing 787 and Airbus 3XX programs will drive future trends (depicted in Figures 1-4, Appendix 1 as presented by Richard Aboulafia of the Teal Group). Additionally, the next generation single aisle competition (B-737 *versus* A-320 NEO) will be a significant factor in retention or loss of market share. These orders represent the near term, however long term trends for their customer base point to a much more constrained and competitive environment. In defense markets, base budgets are already declining; in the U.S., contingency war funding is dwindling quickly, and growth areas seem to be shifting to global unmanned aerial vehicles, intelligence, surveillance and reconnaissance, and cyber defense. This will intensify competition for any new defense contracts and the importance of commercial sales. Along with the market forces, government policy and postures will affect the environment. DOD is pushing for more competition in awards while there is continued movement to firm fixed price contracts that push most risk to the vendor. **The bottom line is that the defense market may not yield as much stability for firms as it has in the past.** This section examines the overall, evolving structure of the large commercial aircraft market (to include areas of future competition by aircraft type); how government policy and approaches will affect it generally; and how the KC-X tanker decision may affect it specifically.

The Evolving LCA Market

Boeing's innovation and manufacturing of the 767 in the late 1970s and early 1980s was a game changer in the aerospace industry. Boeing had modified the 767 in order to increase their range and offer more versatility. To take advantage of the airplane's increased range and long over-water flights new features were added such as: engine and avionics upgrades, winglet

versions, and finally a stretch fuselage version. Boeing was riding high in the late 1980s with the 767. The extended-range version of the 767 family became the most profitable of all Boeing aircraft, including the 747.[5] The 767's other distinctions included becoming the first long-range, transatlantic, twin-engine airliner; it was the first twin-engine jetliner to be approved by the Federal Aviation Administration for Extended Twin Engine Operations (ETOPS) from an alternate airport. This ETOPS for a twin-engine jetliner was a game changer: it allowed more direct, time-saving/cost saving trans-Pacific and trans-Atlantic flights. In the 1990s, Airbus moved aggressively into Boeing twin aisle market with the A330, a new medium size airplane that quickly became very popular with airlines for both passengers and cargo movement. In fact the Airbus A330 was so popular it ended Boeing's dominance of the twin aisle market and it clearly made the 767 days numbered. Boeing, looking for other avenues to get a hold back in the market, launched its freighter version of the 767 in the early 1990s and later its stretch version, both with limited success. Seeing the days of the 767 were numbered, Boeing researched ways to keep the production line going in Everett, Washington.

Movements away from these priorities were slow, but in the 1990s Boeing had changed direction. Boeing's troubles were traceable partly to arrogance, tendency to take the market for granted, coast on its laurels, and partly to changes, like strong risk-aversion, that developed in the corporate culture. Although Boeing remained a well-organized and reasonably well disciplined company in the 1990s, it had grown more hierarchical, heavily bureaucratic-laden, less flexible, and more shareholder focused rather the research oriented. This can be seen in examples from both their commercial and military sales side: David Needham, who grew-up in Southwest Airlines management and became the founder and CEO of JetBlue Airlines, commented that "…in a competition involving two airplanes (Boeing 737's and Airbus 320's) with little to choose between them, winning is likely to depend on strict adherence to first principles, one of which is paying unstinting attention to the customer's interests, large and small. Another is finding the right moment in the campaign to cut the price of your airplane…Boeing neglected both of these principles."[6] Air Berlin, a German low-cost airline, and British Airways who both had been loyal Boeing customers felt the same and switched to Airbus' A320 lines. The same was true for the Department of Defense as a customer, when the Pentagon's inspector general released a report, in regards to the lease proposal modifying the 767 as a tanker for the USAF, which supported the argument that Boeing's influence within the Department of Defense establishment "lays somewhere between remarkable and excessive."[7]

The Tanker Deal

The KC-X program is an ongoing effort to replace the USAF's aging fleet of Boeing KC-135 tankers and has come to symbolize a highly politicized procurement process. Previous efforts to pick a winner collapsed amid protests and procurement controversies. The tanker deal highlighted a divide in the United States over concerns that the American people are continuing to lose manufacturing jobs overseas and the desire to have fair and open government procurement process in which all parties will accept the outcome. Additional issues included the conflict between the concept of the U.S. and European defense companies as partners against common threats and the concept of them as competitors, as well as the concerns of the U.S. incumbent, Boeing, losing its traditional edge.

Recapitalization of the KC-135 aerial refueling tanker is very important for U.S. national security and has a significant impact on the U.S. national budget. Tankers are a critical part of

U.S. military and national security strategy. Without them, air power cannot be forward deployed to overseas theaters in a timely manner and homeland air defense roles/patrols would lose substantial effectiveness. The KC-135 constitutes the bulk of the current tanker force and nearing fifty years of age, it has exhibited some technical difficulties and increased costs of operation. It also has major budgetary implications. The total cost of both operating the KC-135s until they are retired and acquiring and operating their replacements is in the $200 billion range over the next half century.[8] In 2001, a military aerial refueling airplane, the KC-767 (modified 767) was proposed. Boeing and the government attempted to exercise a little used lease acquisition approach to permit the USAF to quickly replace the KC-135E airplanes avoiding capital funding; however, in 2003 the contract was suspended and later cancelled due to corruption allegations.

Why hadn't Boeing been investing and developing a new tanker for the USAF, knowing a new tanker was needed for the U.S. as well as several other nations in the tanker market? Did Boeing have the DoD already in their pocket? Commenting on these problems and losing the world's leading airplane maker title to Airbus, Boeing's CEO at the time, Harry Stonecipher said, "…the long and short of it is we are not engaging with the customers. We don't seem to have a strategy."[9]

In January 2007, the DoD and USAF put out a proposal for a new KC-X aerial refueling tanker to replace the USAF aging KC-135s, whose most recent delivery was in 1965. The KC-X proposal would cover 175 production aircraft and 4 test platforms. The initial total cost for this first phase alone was thought to be more than $30 billion. The USAF KC-Y and KC-Z contracts may follow, which could be worth an addition $60 billion to replace all 530 Active Duty/Reserve/Air National Guard tankers, as well as all 59 USAF KC-10 tankers.

EADS entered the military aerial refueling market first with their A310 line and followed with their A330 line. The Boeing KC-767 and the EADS aerial refueling models were competing worldwide on six aerial refueling contracts with other nations, with Boeing winning two. Reopening the USAF tanker bid in 2007 started an intense competition between Boeing and EADS, who strategically partnered with Northrop Grumman. Partnering gave EADS an American industrial production site, helped EADS euro-dollar conversions, and created a foothold in both U.S. commercial and defense markets. Furthermore, it challenged Boeing's continuance as the only viable player in the U.S. aerial refueling market. The two proposed offers differed from each other primarily in aircraft size, cargo, and fuel offloading capacity. The USAF's Air Mobility Commander at the time (whose command would be receiving the new tankers), General Arthur Lichte, stated "that the KC-45A (Northrop/EADS tanker) provided more passengers, more cargo, more fuel to offload, and that its bigger capacity had been an important consideration in awarding the contract."[10]

This was not the first time EADS triumphed over Boeing in aerial refueling contracts. Some of the reasons for EADS winning other competitions (such as Australia, United Kingdom, Saudi Arabia, and UAE) were their sensitivity to the needs of their customers, their flexibility, and their willingness to make and invest in the relationships. As opposed to Boeing's traditional incumbent role, EADS manifested the behavior of a successful entrant in terms of being innovative and absorbing risk as shown in their fortitude to use their own research and development money to develop and test a refueling boom, which Boeing wasn't willing to do for the customer. Boeing could, after hearing the words about bigger capacity from its customer General Lichte, have used their 777 as a proposal for a larger plane to directly compete with Northrop/EADS. Instead of listening to the customer and focusing on needs, Boeing followed a

two-pronged strategy by attacking the selection process and using its influence with members of the House and the Senate to assault issues linked to EADS being a foreign contractor. Boeing could not dispute EADS's strategy because they were also a contractor in non-U.S. defense markets. Additionally, Senators and Representatives from states like Washington, Kansas, and Connecticut, whose states would benefit from a Boeing award, protested the decision and argued that the Northrop/EADS proposal would send jobs overseas. They were assisted by the labor unions, specifically AFL-CIO and the United Steelworkers Union, who were concerned about sourcing the KC-X tanker contract to a foreign manufacturer.[11] Other threats, tools, and actions were taken by members of both houses in Congress and the committees on which they served to influence the contract award decision (e.g., threats to blocking the President's nomination for a new Secretary of the Air Force, introducing a provision attached to a bill which would force DOD to consider the impact of the tanker contract and future acquisitions on the defense industrial base (which never had been done before), and threats that members of Congress would likely block tanker funding if the contract was awarded to Northrop/EADS.[12]

As their second prong, Boeing filed their protest with the GAO, arguing that the USAF, in order to keep Northrop/EADS in the competition, had changed their requirements during the process. Despite the historical lack of successful protests by firms with the GAO, they upheld only eight of Boeing's one hundred protests (the GAO noted during their investigation they found no evidence of "intentional wrongdoing" by the USAF).[13] Instead the GAO's report focused on the procedural errors in the competition, rather than an assessment of the two proposals.

Impact of the Tanker Deal

The USAF KC-X award is a Fixed Price Incentive Firm contract. This type of contract drives certain types of behaviors, such as Boeing's limiting the amount of money invested to keep the production line open and continue research and development. Boeing's capital, interests, and focus is on their other commercial lines such as the 787, 747-800, and eventually a new 737. As a result, the USAF is getting 30-year-old technology under a fixed-price and incentives based contract. The incentives for Boeing are in production efficiencies and timely delivery, but after the full rate production starts the contract will be strictly a firm fixed price contract, forcing the USAF to pay for any program changes at non-competitive prices. Furthermore, while the competition between EADS and Boeing greatly reduced the bottom-line production price of the tanker for the American taxpayer; is the nation receiving the best value? EADS's tanker, the A330 MRTT, carried more fuel and more cargo, and was based upon newer technology. By contrast, Boeing still needs to design and develop a functioning aerial refueling boom for the USAF's 767 based tanker. With the fixed-price contract, the 767 design lifespan, and other competing internal priorities such as the 787 production and the 737 re-design/replacement, Boeing had no competitive incentive to offer a more technologically advanced aircraft. In the commercial market, most airline companies are prioritizing fuel efficiency, desiring technologically advanced aircraft such as the 787 to replace aging 767s. The USAF also desired an aircraft that was affordable, technologically advanced, and sustainable in both cost and reliability.

Emerging Risks and Issues

Contract Type: Prior to the tanker award, the pending shutdown of the 767 production line threatened the closure of a Boeing revenue stream. It also placed current 767 customers in an unenviable position in regard to technical innovation. Major changes to structural components would be unlikely and too costly to pursue for the existing customer base. Herein lies a major long term risk to the Air Force KC-X program implementation. At some point in the very near future, the 767 production line will effectively be dedicated to KC-X deliveries. Based on stated production rates from Boeing executives, the full lot of 179 KC-X tankers will take about 20 years to complete. During that 20 year period, the Air Force will be locked into a firm fixed price contract for a specific 767 configuration. Any deviation from that configuration will require a contract modification and renegotiation of the terms for deliveries. This means that any technical change in the overall Air Force configuration would drive engineering change proposals with only one bill-payer; the USAF. Per Boeing Commercial Airplanes president and chief executive Jim Albaugh following the award announcement, "Part of ensuring that profit will be protecting against a creep in the scope of work… If additional requirements are needed by the Air Force, that's fine. But they are going to have to pay for it."[14]

Risk Averse Customer: Another set of factors pushing Boeing and other defense contractors to use less innovative approaches, processes, and products are a result of government policy and regulation. The U.S. government's drive to reduce cost and schedule risk has increased over the years and is manifested in the adoption of NASA's Technology Readiness Levels (TRL) (see Table 2, Appendix 1).[15] Government acquisition managers generally seek technologies at TRL 6 or higher. A TRL 4 or 5 is the minimum acceptable readiness level for an incoming technology that will satisfy program constraints.[16] This provides great incentive for contractors to propose clearly proven technologies and not push the envelope even if it was in their strategic interest.

Shifts in Business Models: Many factors have played a role in pushing Boeing into heightened conservatism in regard to innovation and its inherent risks. The corporate culture, the focus on near term shareholder value creation, and the reluctance of the U.S. government to accept a large share of risk has encouraged a slower, incremental approach to change that imparts reduced levels of leading edge technology in defense products. Additionally, the changes in the global business environment are pulling commercial innovation away from U.S. shores. Over the past ten years Boeing has led in innovation of business relationships and processes on a global scale via the 787 program. While the technical innovation of using large amounts of composite structures is the hallmark of the program, it can be argued that the manner in which the supply chain was globalized is even more far reaching in its impact. The new partners were made responsible for research, development, design, and manufacture of significant sub-systems and structures. This means the lion's share of innovation will be taking place at the sub-system level and outside of Boeing proper. This has at least two effects: 1) as intellectual property, any technical innovation is owned and controlled by the off-shore partner and 2) the knowledge and skill base to innovate has shifted to the off-shore partner. If the decision was made to become an integrator of subsystems in the creation of a final product, short-term value creation and risk reduction may have been optimized. However, in the long term Boeing may be giving up considerable strategic competitive advantage in the market. A key indicator of Boeing's move in this direction was the sale of their Commercial Airplane business units in Kansas and Oklahoma

to the Onex Corporation of Toronto, Canada in 2005. The resultant company, "Mid-Western Aircraft Systems is now the world's largest independent supplier of structures for commercial aircraft. It will remain a major supplier partner on the 787 program and supply fuselage and other structural components for the 737, 747, 767 and 777."[17] Boeing's core competency appears to be moving to large-scale systems integration and away from technical innovation at a sub-system level.

Competing Opportunities: The current schedule for KC-X development and production may have repercussions on overall Boeing planning and execution of other projects. The 2011 to 2017 schedule includes development and integration of the refueling boom (based on KC-10 configuration), a retrofitted 787 cockpit configuration, and delivery of 18 aircraft. These are complex tasks that will consume engineering, test, development, and production time and personnel. During this period, extensive work will have to be accomplished on re-design or replacement of the 737 series, while ramping up production capacity for the 787. Delaying the 737 decision and ongoing battles for locating expanded 787 production will likely stress resources and schedule across Boeing. It is highly unlikely that USAF will provide any schedule relief for KC-X and Boeing competitors will leverage any 737 delay to their advantage in the single-aisle market. Timing is everything in the market, and Boeing's margin for error is thin.

The Hand of Government: The role Congress played in the awarding of the KC-X contract could set important precedents for the acquisition process. The initial awarding of the KC-X tanker contract to Northrop/EADS suggested that the government acquisition process does not always favor the incumbent; that there is an increasing emphasis on obtaining the most appropriate product at the best cost and that a transparent and open process will include foreign competition. This was the main thrust of former Secretary of Defense William Perry's efforts while in office (1994-1997); aimed at restructuring defense acquisition policies and procedures. Perry's reform agenda concentrated on simplifying purchasing decisions, increasing reliance on existing commercial products, and conforming military contracts, bidding, accounting to commercial practices. He emphasized that competition was healthy for the defense industry. This competition will bring out the best platforms for the warfighter and their needs.

This view is also endorsed in the 2008 Annual Industrial Capabilities Report to Congress by the OSD/AT&L on the specific topic of globalization and international competition. The DOD objective is to "…leverage globalization benefits and commercial markets while minimizing risks."[18] Furthermore, the document states, "Even if the Department could afford to rely only on domestic sources, it would not want to. The United States does not own all the good ideas, nor make all the best products. Many of them come to us from our allies and trading partners…The Department does not, and cannot, drive global commercial markets. Instead of hoping that global commercial markets will adapt to the Department, the Department must adapt its practices to be more of a conventional customer wherever possible."[19]

The defense industrial base, especially aerospace, highlights the SCP model: according to the model an industry's performance depends on the conduct of its firms, which then depends on the structure. Government, if not careful, can exercise undue influence within the SCP paradigm and incentivize actions contrary to its strategic interests. The above views are consistent with recent statements of one of Perry's associates, Dr. Ashton Carter.

With the recent Boeing award of the KC-X tanker contract in February 2011, observers point out that price, rather then value, was the overriding factor in choosing a winner. This

award allowed the American taxpayer to avoid approximately $16 billion in up front costs as a result of the competition. Along with the savings, members of Congress expanded the debate on U.S. jobs, ignoring the fact that both proposals would produce roughly the same number of U.S. jobs. The difference lies in the location of the U.S. jobs; however, this brings up bigger questions. In defense acquisitions, should job creation and their location be a primary factor at the expense of competition, increased costs, and possible trade retaliation?

The role that Congress played in the USAF KC-X tanker suggests that political considerations, when at odds with military requirements, could take precedence. The impact of this award being perceived as driven by domestic political considerations may lessen foreign firms' desire to compete for future U.S. defense projects. As a result, one might experience reduced access to global economies of scale, thereby increasing costs and limiting innovation. Thus, the emerging dichotomy could be defined as the desire for a fair and open government procurement process which leads to the best product with the political concerns of losing U.S. manufacturing jobs overseas. This tension could force a prioritization of U.S. government's objectives with regard to the already perceived "co-opetition" among U.S. and foreign defense companies in the global marketplace.

Potential Effects and Consequences of the Tanker Deal

A Resource Sink: By extending the life of the 767 line, Boeing is dedicating physical plant space, engineering staff, capital equipment, management, and production workers to a technological dead end. The production supply chain will have to be maintained to support scheduled deliveries. In some cases after 30 years, the original suppliers are no longer in existence and replacement parts have to be generated via Boeing in-house custom machining capabilities. In considering the engineering staff, the attractiveness of working on a design baseline created 30 years ago is likely very low. What is the likelihood of the best engineers being assigned to work the 767 program vice the 787 program or a next generation replacement for the 737 product line? Another risk is in dedicating skilled production staff and engineering staff to a product line that does nothing to advance their skills or introduce them to new design and manufacturing techniques and processes. Retention of skilled staff on a KC-X program may be difficult and the staff that can be attracted may not be the acme of professional skills.

Running in Place: Finally, the extension of the 767 line will not yield much in the way of technology to move the bar higher in new products. It is definitely not going to push technology to new heights. "Bringing the KC-X to Seattle won't add anything much long term; it really just delays the inevitable closure of the commercial 767 line."[20] Viewing the production footprint for the 767 line begs the question "what else could this space be used for instead?" The physical footprint and tooling represent an investment in the tactical past and not the strategic future. The space, tooling, and staffing would more likely boost Boeing's market position if it was dedicated to additional 787 production, a next generation 737, or a 737 replacement to compete directly in the single aisle aircraft market.

Gap Bridging: It doesn't appear Boeing is gaining ground in a market which is looking for new, innovative, efficient, high performance commercial aircraft. Boeing may have decided that dropping the 767 line was too risky from a financial perspective given the lagging schedule for delivery of the 787. One can appreciate them hedging their bets on offering 767s at minimum

price as short term substitutes for anxious 787 customers. The KC-X award could be viewed as a means of keeping that option alive while 787 production ramps up.

Competitor Positions: Airbus has acquired some uncontested room to maneuver in the market. While the loss in the KC-X competition stymied EADS' attempt to gain a major footprint in the US defense market, it may have reduced Boeing's ability to rapidly counter future EADS challenges in the US and globally for tankers and other aircraft. Furthermore, EADS has experienced strong sales and profits over the past year leading to a "$16.6 billion 'war chest' that the European giant might open to gain a stronger foothold in the United States, the world's largest defense market"[21] The entry of EADS into Boeing's backyard could come in a number of forms. EADS has been open about its plans to expand into the US market through products and services, or by acquisition of North American firms. After the first KC-X award was nullified Louis Gallois, CEO of EADS, stated, "If we want to be in the US, we have to buy companies. We are not changing our wish to create a footprint in the US… EADS is actively pursuing a "mid-sized acquisition."[22] A few days after the final KC-X award on March 24, 2011, EADS announced "that it was in exclusive talks to purchase Vector Aerospace, a Canadian company that repairs and maintains civil and military helicopters… EADS has a target to achieve $10 billion of US non-Airbus sales by 2020 and another goal of balancing its revenues more evenly between cyclical commercial sales and more stable defense work. If successful, this would be the first North American purchase since 2008 when it bought PlantCML which makes emergency call centers and control rooms"[23]

Another prospect for bringing an innovative EADS product to US soil is in tactical air transport via the Airbus Military A400M. While the A400M has suffered initial setbacks in its design, development, and delivery; some at EADS believe "The A400M could compete for any future airlifter requirement as the US looks to replace its Lockheed-Martin C-130 fleet."[24] Beyond EADS, other firms are expanding their reach while Boeing seems to be temporarily limited by current commitments to the KC-X and 787 production ramp up. On February 24, 2011, "Bombardier and the Commercial Aircraft Corporation of China Ltd. (COMAC) announced that they will explore collaboration in marketing and customer service in an effort to help each other increase market share in both emerging and established markets. The deal aims to establish long-term co-operation on commercial aircraft and possible co-operation on Bombardier's C Series planes and COMAC's C919 model and future products. Boeing has dubbed the Chinese narrowbody the most significant threat to the Airbus/Boeing duopoly. Boeing forecasts that the Chinese market will represent 14 per cent of global deliveries in the 2010-29 timeframe."[25] In recognition of this expanding competition, the head of EADS, Louis Gallois said, "'some kind of consolidation or partnership was required in the narrowbody market'. He expects EADS to partner with Brazil's Embraer to develop a new aircraft."[26] Both entities could bring a new narrow-body commercial airliner to market in the near term, while Boeing ponders providing a redesigned 737 or developing a new product to compete in this rapidly expanding sector of the commercial aircraft market. In either case, the window of opportunity is narrow and the market seems to be looking for new efficient products, not re-worked designs; even if they have served well over the past 20-40 years.

Capital Generation: With the current demand and heavy capital investments in both Boeing's 787 and 747-800 projects, Boeing needs to get the 787, their game changer, moving forward and producing capital for the company. More and more pressure will be exerted on Boeing in the

single aisle 737 market from its customers, competitors, and newcomers like Brazilian Embraer, Canadian Bombardier, Russia, and China. Boeing hopes to make a new 737, which they hope will be a game changer like the 787, and figures it will have time after they work out the 787 problems. Only time will tell if Boeing has learned from past mistakes especially as globalization, increased competition, and government interests come to the market.

Large Commercial and Military Aircraft Conclusions

Government procurement policy ensured that the KC-X tanker was a competition in order to drive to best-value for DoD. However, the result appears to have resulted in lowest price vice best-value. The tanker deal highlighted a divide in the United States over concerns that the American people are continuing to lose manufacturing jobs overseas and the desire to have fair and open government procurement process in which all parties will accept the outcome. Additional issues included the dichotomy between the concept of the U.S. and European defense companies as partners against common threats and the concept of them as competitors.

While the current policy is to be commended as a path to drive out the best value regardless of source, procedurally circumventing its intent appears to be possible. The majority of acknowledged protest items on the initial award was process based and not issues of technical merit. Hence, the second competition seems to have devolved to a "lowest price" win. As a result:

- USAF will be accepting a product based on a thirty-year-old design and technology, with little opportunity for leveraging technical innovations for the full product lifecycle.
- Boeing will be devoting resources to a product effectively at the end of its commercial shelf-life.
- Foreign competitors may initiate retaliatory actions against U.S. businesses abroad (if the tanker competition is not perceived as a real and fair competition) or more aggressively pursue direct investment in the U.S. to more strongly compete in future DoD procurements.
- The outcome of the "next competition" will be confirmation to many parties if there is real competition in the U.S. or if they are only a convenient lever to drive down prices of U.S. vendors.
- Future competitions must be fully transparent and resist political pressure that could drive the award from best value to "most expedient" value.
- Future policy must address how the U.S. defense industrial base and government will align with foreign partners. This could take the form of associations permitting a freer flow of technology through joint ventures, partnerships, and direct foreign investment in the domestic aerospace industrial base.

Strike Fighter Market and F-35 JSF

One of the major shifts to occur recently in the U.S. strike fighter market is the overall effect of consolidation in the defense industry reducing the number of prime manufacturers of strike fighter aircraft. The effect of the 2001 winner-take-all decision on the JSF contract led to the current domestic fighter market in the U.S. being only able to sustain a single major prime, Lockheed Martin, with Northrop Grumman providing major sections of the aircraft.

The strike fighter Foreign Military Sales (FMS) market, however, offers opportunities for Boeing and Lockheed Martin to sustain production lines for F-15, F-16, and F/A-18 strike fighter aircraft. See Appendix 2 for strike fighter production and potential international strike fighter sales. A market for these aircraft still exists for countries desiring a highly capable and lower risk platform when compared to a new program or when a high level of domestic Industrial Participation is required as in India, Brazil or Japan. Alternatively, these aircraft provide an alternative when a preferred aircraft, such as the JSF is unavailable, either due to political restrictions on sales or due to development and production delays. Further delays of the JSF could extend the market for such fighters, as in the case of Australia, as well as increase the viability of competition outside the U.S. to expand market share, such as the Eurofighter. (See Appendix 3 for an analysis of the India Medium Multi-Role Combat Aircraft (MMRCA) competition.)

Ultimately, it is expected that with stagnant or decreasing procurement dollars in the U.S. market, global sales are imperative to maintaining the current size and health of the domestic fighter industrial base. Should Boeing successfully compete internationally with the F/A-18 E/F Super Hornet, the U.S. could maintain a second domestic fighter prime manufacturer beyond the current production run of Navy FA-18 requirements.

Achieving value in the strike fighter market

For any business to succeed within a given marketplace, over the long term it must produce value. In a commercial market, evaluation of a firm's competitiveness can be judged by its ability to provide return on invested capital. If a firm or market ultimately is unable to provide a suitable return on investment, it will soon be unable to independently operate without outside support. The defense market in general and the strike fighter market in particular will respond in a similar fashion. However, distinct from a commercial marketplace, value generation within the aircraft sector must be viewed through two additional paradigms: the health of the industrial base and the ability to produce articles supporting a nation's security requirements. The balance of these three priorities, return on invested capital, maintenance or production of a strategic industrial base, and the capacity to acquire needed defense articles will vary over time and from nation to nation. Taken together, they will, however, determine how a nation determines value within the defense market.

Balancing value generation between monetary returns, job creation, and industrial capacity to innovate will ultimately be decided by political imperatives surrounding the allocation of scarce resources. While the total value of global defense articles are projected to increase over the next decade, how each nation defines value in their respective strike fighter markets vary considerably. The US defense market, writ large, while experiencing a long term trend toward consolidation, has historically been large enough to domestically satisfy market requirements for return on invested capital, military requirements of technological capability and

innovation, and the strategic requirement for the preservation of an industrial base and its associated jobs. Current budgetary pressures, however, could challenge this paradigm, and assuming the threat environment doesn't change dramatically, these budgetary pressures could ultimately diminish the capacity of the U.S. domestic market to meet all three definitions of value generation. Should this occur, the U.S. will be forced into an evaluation similar to what Europe has experienced in the past two decades, and potentially will have to choose its priority of value.

Competition in designing and developing a next generation strike fighter will be vital for maintaining the capacity to create value from a national security perspective. Obtaining financial support to spur innovation in the strike fighter market will likely face an imposing resource challenge. The Congressional Budget Office estimates the share of the defense budget spent on research, development, test, and evaluation will decrease based on the Future Years Defense Program.[27] Any large future R&D budget reduction will threaten resources needed for design and development of a new strike fighter. The DoD will need to prepare compelling arguments to Congress and accurately assess the rising threat to U.S. air superiority posed by new fighter and surface to air missile development emerging from Russia, China, and potentially new national actors.

Areas experiencing the greatest growth of defense budgets, such as the Middle East and Asia, represent another view of the value balance. While the Middle East has purchased military capability primarily for to meet security requirements and political factors, Asian nations have sought the strategic development or enhancement of their domestic industrial base as an equal, if not greater, priority to any specific military requirement. Both China and India have focused efforts on advancing their own domestic production capabilities while recapitalizing their fighter fleets to 4th generation airframes. Chinese, Indian, and to a similar extent, Brazilian, fighter markets will continue this prioritization of value determination as long as their financial position allows does not change significantly and their industrial base lacks the capacity to organically meet their security requirements.

Porter's five forces analysis of the military strike fighter aircraft market

Using the five forces model, a successful JSF program will only increase market trends currently underway. Given the immense capital, production requirements, and expertise required to initiate and manufacture fighter aircraft, the threat of new entrants is very low and rivalry among competitors is extremely high. Despite the fact that governments are currently the only buyers for fighters, their relative bargaining power is somewhat reduced as compared to a non-defense market. The lessened bargaining power is mainly due to the political power of the aircraft sector and due to the political power and military requirement faced by the services in terms of recapitalization requirements. Suppliers also hold moderate power as global supply chains, once established, can be difficult to rapidly change.[28]

Each of the above components of industry analysis would appear to remain constant should JSF continue to track correctly. Once production is up to full speed, lack of any alternative stealth fighter attack aircraft would only serve to increase competition among the remaining entities fighting for their share of the 4th generation marketplace. And while Russia and China have a 5th generation aircraft in development in the form of the PAK-FA and the J-20 respectively, given their issues with engine reliability, their ability to compete in a direct value basis against US fighters remains questionable in the short term. The fighter market, however, is

not one of perfect competition. Even assuming Lockheed Martin is able to affordably produce and support the F-35, political impediments to foreign military sales will eliminate some potential buyers. Each of these buyers will be courted aggressively by the remaining aircraft producers, offering enticements such as technology transfer and work share agreements to increase the potential for sales.

Of the five forces, the threat of substitute products or services represents the largest unknown over the mid to long term. Over the past several decades, western fighters have generally developed into two realms: the air dominance fighter, as represented by the F-15 and F-22 today and the multi-role strike fighter, such as the F/A-18 and F-35. While the air dominance fighter has no current substitutes, the manned multi-role strike fighter is starting to face real alternatives in some mission sets. Even as today's unmanned aerial systems (UAS) are still generally viewed primarily as a reconnaissance platform, armed variants will certainly provide both nations and ultimately non-state actors options to round out their portfolios during the projected lifecycle of the JSF program. Given the current trend of lower procurement, training, operation and maintenance costs for UAS, fiscal reality will drive potential substitutions as much as future technology will.

Assuming the restructuring efforts are successful, and the long-term costs are as hoped, JSF and its global partnership will not only affect how firms conduct business in the fighter market, but could potentially redefine the structure of the industry. The current global industry structure can be best described as an "'oligopsony', with a limited number of buyers that have significant market power but not total control of the market."[29] Looking solely at the U.S. market, two defense primes, Lockheed Martin and Boeing, currently produce fighter aircraft while a third, Northup Grumman, supplies major portions of the Joint Strike fighter and Super Hornet and retains significant aircraft experience as a developer and integrator. In addition to U.S. companies, one European Consortium (Eurofighter) currently is in production of the Typhoon, with additional international competition from the Russian United Aircraft Corporation in the form of MiG and Sukhoi aircraft and the FC-1 from Chengdu in China. France's Rafale and Sweden's Gripen NG round out the remainder of competition.

The European defense market, faced with declining national defense budgets have increasingly relied on increased cooperation and integration to preserve a European industrial base and maintain freedom of action. While some European nations have opted to seek the greatest technological capability available by joining the Joint Strike Fighter program, the Saab Gripen and Dassault Rafale represent an alternative option of prioritizing the maintenance of organic industrial capacity over other concerns. The EADS Eurofighter represents a third choice, sacrificing total domestic control over aircraft products in order to increase the potential for financial return while diluting risk and allowing for the maintenance of high technology sectors within each partner nation. Alongside these partnering arrangements, penetration of the North American defense market, while simultaneously increasing sales to the Middle East and Asia, is a critical component of the European strategy to offset diminishing domestic defense budgets.

In terms of overall size, the global defense market is expected to grow over the short term, even factoring diminishing budgets in Europe and limited growth in the United States. While the United States currently represents by far the largest single defense marketplace, growth in the Middle East and Asia represents the largest opportunity to expand fighter sales. And in recent years, American corporations have been more successful then European companies at taking advantage of these opportunities.[30]

Should a collaborative European combat aircraft program follow Eurofighter, it will most likely be an unmanned platform. The Neuron unmanned demonstrator, involving France, Greece, Italy, Spain, Sweden, and Switzerland, has scheduled flight demonstrations in 2013 to evaluate cutting edge combat aircraft technology. The U.K. is likewise testing stealthy UCAV technologies in its Taranis unmanned demonstrator and is using the program to sustain combat air vehicle design and development skills within the U.K.[31] Additionally, the Franco-British defense cooperation treaty signed in November 2010 will be the basis for a possible cooperative venture in a follow-on demonstration program combining Neuron and Taranis demonstrator technologies. France is studying the proposed five-year follow-on program. A road map for common technology development is scheduled for completion in 2012.[32]

In addition to the development of the above potential substitutes, 5th generation threat aircraft are also currently in development in China and Russia. China is developing and testing the new Chengdu J-20 fighter, which bears strong visual resemblance to the F-22 and could possess fifth generation stealth characteristics. India and Russia are cooperating on the development of a Fifth Generation Fighter Aircraft (FGFA) based on the Russian PAK-FA Sukhoi T50. As noted by the website of the Russian Embassy in India, "India and Russia are set to sign their biggest-ever defence deal with the government's highest decision-making body clearing a mega proposal for joint development and production of a fifth-generation fighter aircraft (FGFA). The total projected value of the deal is pegged at $30 billion, with the Indian Air Force (IAF) looking at placing orders for 250-300 of the advanced fighters."[33] These competitors create urgency for the U.S. to successfully execute the JSF program while also considering what will follow it as a next generation of capability. (See Appendix 4 for a strike fighter firm analysis.)

JSF from a Partner Perspective

JSF partners made significant investments in the JSF program and have signed a JSF Production, Sustainment, and Follow-On Development Phase (PSFD) Memorandum of Understanding. The partners closely monitor progress in JSF program development. According to industry sources in Europe, even with recent progress, sources of friction in the program include increasing cost estimates and associated risk, the five plus year schedule slippage for full rate production, work share distribution, adequate technology transfer and ITAR compliance, potential weaknesses in the global logistics system, dependence on U.S. infrastructure, and a perceived lack of operational sovereignty. Such concerns aside, international cooperation in the JSF program provides an affordable avenue for acquiring fifth generation strike fighter capability built upon cost and technology sharing, optimizes interoperability, and fosters best value industrial participation opportunities. [34] The JSF partners will seek these goals and any definition of success in the JSF program must include achievement of these goals for the partners. Slippage in the JSF development schedule has already led to one partner, Australia, needing to procure twenty-four F/A-18 Super Hornets to bridge the capability gap caused by delayed introduction of JSF into its inventory. More delays in JSF development could force other partners to consider similar decisions and lead to further erosion of confidence in the program, directly challenging a prime component of the JSF program: affordability.

The JSF Affordability Challenge

Porter's five forces, however, only partially define the market in which fighter aircraft manufacturers operate. While market forces and shareholder value drive much of what the U.S. and European aircraft industry responds to, the strategic nature of this sector ensures that its operation will remain highly politicized regardless of the outcome of the JSF program. Within this political environment, "the drive for innovation to meet new twenty-first century military requirements and the drive for affordability in an era of increasingly constrained budgets and rising weapons costs — converge to create powerful incentives for governments to allow more open and competitive markets."[35] The conflict between affordability requirements, political influence, desire for innovation, and interoperability among allies will ultimately decide to what level markets will be opened and to what extent national champions will be protected.

A successful JSF program must be managed within the above construct. By integrating European aerospace industries within its supply chain, the program has provided financial incentives for program partners to drive success.[36] While the program has developed work share agreements across the foreign partners, from the outset it avoided *Juste Retour*, a practice still common within the European defense establishment, and instead has focused on obtaining best value.[37] As evidenced by the U.K experience with the Eurofighter program, balancing coalition partners and best value can be difficult to manage successfully. Citing program difficulties which "proved complex and inefficient", the bulk of cost overruns within the Eurofighter program were largely attributed due to "to the inefficient collaborative commercial and managerial arrangements, [and] obligations to international partners."[38] Of note, despite initial concerns over the management of the program and the implementation of measures such as fixed price contracts to correct cost overruns, the end state was a fighter with costs dramatically higher than original estimates.[39] Given that the JSF represents a greater level of technical difficulty and possesses more stakeholders then the Eurofighter, efficient program management of the JSF would appear to be more challenging. If, however, the program is able to overcome these inherent challenges, it could provide a benchmark for future European / U.S. defense projects and could facilitate the further opening of these markets. If this program fails to achieve its objectives, European nations may be more reticent to join future joint ventures.

In addition to impacting U.S. participation in the European market, the success of the Joint Strike Fighter program would also validate the use of a joint and combined acquisition process to lower overall costs. Breaking the long term trend of "unit cost increases... [at] greater than the rate of inflation"[40] is of critical importance, particularly given the expectations that the JSF is advertised to ultimately provide 5th generational capability at a 4th generation cost. This cost basis is exceptionally important because "the main source of cost escalation for aircraft is customer-driven factors", also known as requirement creep.[41] If successful, the JSF program model would certainly validate lean manufacturing techniques, global supply chain advances, and the program management principles employed by Lockheed Martin.

In addition to validating the lean production line and lifecycle product support using performance based logistics, successful execution of the JSF program will certainly have an impact upon the U.S. industrial base and future innovation. Assuming the JSF fulfills Lockheed Martin's goal of replicating the F-16 production run on a global basis, the program will certainly consume a large portion of available capital for aerospace products. Should Lockheed Martin succeed, with relatively limited funds available for alternatives, alternative domestic production lines, such as the FA-18 E/F/G and international production runs of the Eurofighter will

undoubtedly face pressure to demonstrate value or perish. While political forces could certainly intervene to maintain these production lines, supporting them could have the secondary benefit of providing an alternative avenue for incremental innovation.

In its March 2011 report on the Joint Strike Fighter program, the General Accounting office noted favorable trends for the troubled program. Given the level of importance of this program to not only the United States, its eight international partners and their representative aerospace sectors, this news could not have come at a better time. And while the program partners hope the next ten years prove smoother then the first ten, whether the F-35 Lightning II, the "Department of Defense's (DOD) most costly and ambitious aircraft acquisition", successfully fulfills its programmatic goals of developing an affordable, survivable, lethal, and sustainable stealth aircraft has yet to be proven.[42]

Should it succeed, this first truly joint and combined aircraft acquisition program will not only provide a template for future procurement, it will have a profound impact on the market for manned fighter aircraft. Likewise, if it fails to meet its most critical pillar, that of affordability, there is more at stake than simply continuing the historical trend of ever-increasing costs as stated by Augustine's 16th law.[43] Failure would not only continue a post cold war trend of rising costs leading toward structural disarmament, it would force a reexamination of the critical defense-trade linkages among U.S. allies and ultimately force the reassessment of the value that manned fighters provide in a nation's defense portfolio.

Defining the successful execution of a military acquisition program depends primarily upon the perspective of the viewer. While successful execution would normally include analysis of the program's ability to meet or exceed the Key Performance Parameters (KPPs) as established in the System Design and Development (SDD) phase within the defined cost and schedule, this analysis will argue that in order for the JSF program to be considered successful, it must meet its KPP's affordably. For the JSF program, such affordability is more than simply the flyaway cost of the aircraft. A central feature to the JSF program is its focus on "reducing the development cost, production cost, and cost of ownership of the JSF family of aircraft."[44] Meeting this lifecycle cost challenge will not only ultimately define the level of success that the JSF program achieves; it will also be one of the most important strategic drivers for the future of manned fighters.

Given the fiscal challenges faced by the United States and her allies, the importance of affordably recapitalizing aging fighter fleets cannot be overstated. The program thus far, however, has been challenged repeatedly to live up to its promise. While any new aircraft start is a complicated endeavor, the JSF program has had its critics from the start. The GAO's report in May of 2000 highlighted serious concerns over the JSF's development schedule and questioned the program's ability to meet both its cost and schedule targets. Despite the Department of Defense's claims that the aircraft could be produced in a range between twenty-eight to thirty-five million dollars, the Congressional Budget Office estimated costs would likely be 50% more.[45] Eleven years later, after restructuring the program multiple times and accepting a five year slide in the development schedule, the original projected developmental baseline cost of $34.4 Billion in 2001 has risen to $56.4 Billion today.[46]

Cost estimates per aircraft have grown as well. Failure to meet developmental targets of cost and schedule, while symptomatic of the defense aerospace acquisition process, remain only part of the problem. As "aircraft, satellite, and helicopter programs have [historically] experienced the largest number of [Nunn-McCurdy] breaches", the fact that a program as complicated as the F-35 faces challenges should not be surprising.[47] Assuming Lockheed Martin

is able to overcome the significant hardware, software, and production challenges ahead and meets the requirements necessary to proceed to full rate production in 2016, issues of driving down production and lifecycle costs remain a further challenge. The 2001 planned production run of 2,866 aircraft was expected to cost $233 billion dollars, averaging 69 million per unit, or an amount comparable to a current 4th generation fighter.[48] Following the 2010 Nunn-McCurdy breach, the total program acquisition cost had risen to $382.5 billion, or 133 million per aircraft for the run of 2,457 aircraft.[49] Despite these challenges, Lockheed Martin has confidently stated that the unit recurring flyaway cost, or cost with R&D or other sunk costs removed, will be only slightly higher than a current F-16, or approximately 60 million dollars in today's dollars.[50]

With no shortage of controversy, alternative estimates have varied widely. Other estimates agree with Lockheed's statement that it will achieve $60 million per copy, primarily due to the fact that "Lockheed knows it can't price the plane much above an F-16 without driving away prospective buyers."[51] Still others are less enthusiastic, citing production challenges on previous stealth aircraft that failed to fully achieve cost savings expected as a production learning curve improves.[52] Should the learning curve not provide cost relief and program costs remain as predicted or even grow, the F-35 could face a similar "death spiral" as seen with the F-22 or the B-2 and cost upwards of 200 plus million per aircraft.[53] Ultimately, successful management of program complexities will determine if the JSF program is able to bring down production costs as hoped. Should production costs come close to planned, the program will have met its primary goal of cost affordability despite the technical delays and developmental cost overruns,

Delivering on its promise of a diminished lifecycle cost will be the second critical programmatic challenge for the JSF program. With the total acquisition cost of the JSF expected to exceed one trillion dollars, development and procurement cost represents roughly a third of the total investment.[54] While success in this arena will not be fully understood for perhaps decades to come, assuming Lockheed Martin is able to leverage its global supply chain and effectively manage the performance based logistics criteria as planned, the final affordability goal will be met and the program can be defined as a success. See Appendix 5 for issues with supply chain management in the drive to affordability and reliability.

Next generation strike fighter and impact of JSF on future competitiveness in the U.S.

A successful JSF program will also impact how we think about the future of manned fighters. Although the JSF is currently scheduled to remain in production until 2035, given the twenty plus year developmental cycles for modern fighter aircraft, the Air Force and Navy have already started asking what happens after JSF. With a December 2010 request for information titled "Next Generation Tactical Aircraft (Next Gen TACAIR) Materiel and Technology Concepts Search" and the Navy's next generation air dominance (NGAD) analysis of alternatives, each service is attempting to determine what level of innovation to focus upon.[55] A successful JSF program will certainly impact this decision making process. Failure to meet program affordability objectives will, at the minimum, increase the recapitalization requirements of all air services while simultaneously expending valuable resources. Should program failure occur, unless the threat environment dramatically alters national priorities, the capacity to produce a follow on fighter in numbers as envisioned by today's requirements will be extremely strained. Furthermore, without a sizeable production run, the national capacity to maintain several aircraft primes capable of building a 6th generation fighter will be equally strained. At that point, the nation will have to make difficult choices in order to determine how best to

maintain the innovation required to maintain a technological base necessary for the next leap forward in aviation.

Rand's extensive study "U.S. Combat Aircraft Industry, 1909–2000: Structure, Competition, Innovation" chronicled major aircraft innovation periods from the biplane through stealth development and offers some level of insight into potential future trends. Cataloging a commonality of intense competition at the start of each new period of technology, similar to the down select for the Joint Strike Fighter, they noted that in the years following, industry typically entered a period of refinement vice breakthrough.[56] Assuming the JSF program fails prematurely, unless a surprise technology presents itself, it would be expected that industry would follow upon incremental improvements of current technology. For example, a development along these lines would certainly seem to benefit Boeing by extending the Super-Hornet or Eagle production line through such incremental modifications.

Rand also noticed that following a period of technological innovation, **"**new dominant industry leaders among prime contractors/integrators emerged in key specialty areas in combat aircraft."[57] Two other points are worth highlighting. First, "competition to innovate during these periods was usually triggered by factors related to increased market demand, various technology developments, and military threat perceptions and system requirements." Secondly, prime contractors during periods of technological breakthrough "were most often not among the industry leaders of the prior technology-refinement era."[58] While the nation currently has fewer primes capable of manufacturing aircraft then were present during the bulk of the survey, it is possible that a similar pattern as described above could occur again as technology continues to develop. Such a pattern would appear even more plausible if unmanned aerial systems continue to develop at a rapid pace.

In addition to the fact new industry leaders or industry teaming arrangements could be responsible for the next innovative leap, Rand's analysis of why innovation occurs is instructive. Primarily driven by market demand, the next generation of aircraft would be constrained by the art of the possible in terms of existing technology levels while being required to operate within the perceived threat environment. In today's terms, a possible definition of the next generation of fighter technology would have the following characteristics: "multi spectral stealth; efficient in all flight regimes (subsonic to multi-Mach); possible "morphing" capability; smart skins; highly networked; extremely sensitive sensors; optionally manned; directed energy weapons."[59] And, with the assumption that the JSF program failed, it would likely be very expensive to develop and produce.

Success or failure of the JSF program, therefore, will ultimately drive more then just the state of the industrial base, the ability to innovate for future threats, or current defense trade linkages. It could also potentially alter the perception of the market as known today. When estimating the total demand for fighter aircraft in the near future, the Program of Record for the Joint Strike fighter is balanced versus the expected capacity of the United States, allies, and partners to purchase the produced quantity. A successful program, with the F-35 demonstrating affordable capability, would guarantee a greater number of operational fighters present among the military services of the world than one would expect should the program fail. The presence of such a number of fighters would certainly provoke a reaction by those nations unable to buy into the program. Potential options would be to increase their own efforts to produce or purchase a similarly capable offensive aircraft, increase their defensive capacity in the form of sensors and ground-based weapons, seek asymmetric capabilities, or choose not to play.

Failure of the JSF program, with the concordant ramifications of ultimately lowering the total number of friendly operational fighters, would have the potential for lowering the total perceived need of adversary fighter aircraft as well. While the market may be diminished in overall numbers, the market would by no means be eliminated. As currently evidenced by Iran and China, nations with capacity and desire are proceeding with efforts aimed at countering the ability of the United States to project power.[60] Failure would, however, certainly impact the ability of some nations to afford large numbers of manned fighters. Logically, some of these nations would either choose not to play, or to play at a diminished capacity relative to what they are able to do now. Others would continue the search for asymmetric or alternative defensive options as part of their portfolio to protect against those nations choosing to maintain fighter aircraft. Regardless of the path, the success or failure of the JSF program will certainly impact the fighter market for decades to come.

The F-22 and F-35 will provide exceptional fifth generation capability to the U.S. JSF, as the preeminent international strike fighter cooperative program with our allies and partners, will dominate the global strike fighter market in sales and deliveries for many years. Richard Aboulafia of the Teal Group predicts that "unless some kind of new-generation counterweight to F-35 emerges, everyone other than Lockheed Martin and Sukhoi will either have moved on to different types of work, or be a fighter subcontractor, or merely on borrowed time."[61] Although Lockheed Martin F-35 dominance of the strike fighter market is far more desirable than a widely exported foreign competitor with large market share, a single dominant manufacturer in the U.S. domestic market could stifle innovation, inhibit technological advancement, and create an affordability challenge for DoD and the taxpayer in developing the next generation strike fighter.

Since complex strike fighter aircraft require substantial lead times for design, development and production, a new next, or sixth, generation strike fighter should be fairly deep into development at this time, even as we introduce our latest fifth generation aircraft in the F-35. Unfortunately, that is not the case. As noted in 2009, "hanging over the sixth generation fighter debate is this stark fact: the relevant program should now be well under way, but it has not even been defined. If the Pentagon wants a sixth generation capability, it will have to demonstrate that intent, and soon."[62]

Defense industrial base and aircraft engineering competency considerations

Currently, there is no new U.S. strike fighter Program of Record in design and development. When the F/A-18 E/F Super Hornet ends its production run for the U.S. Navy in 2015, for the first time in decades, there will only be a single U.S. strike fighter manufacturer with an active production line, Lockheed Martin and the F-35. Should the U.S. proceed with a next generation manned fighter, Lockheed Martin would be the single U.S. manufacturer with significant large-scale recent strike fighter aircraft engineering design and development expertise. However, since most of the design and development work is maturing on JSF, even its prime contractor Lockheed Martin is currently losing vital specialized aircraft engineering design and development workers to other industries.

Companies seeking to stand up requisite engineering design and development staff anew to compete in a next generation competition would face a rigorous business challenge. The Aerospace Industries Association reports "interruptions in design and development activity will ultimately have serious consequences – intended or unintended – that will change the composition and technical capabilities and the aerospace and defense workforce itself.[63] In a

2003 study by RAND, "data provided by the three prime contractors for the present study suggest that the size of a design team in the current environment ranges between 1,000 and 2,000 engineering and direct support personnel at a cost of $250 to $500 million annually."[64] Even large highly capitalized aircraft manufacturers would find this work force and economic requirement difficult to absorb.

On Sept. 28, 2010, the U.S. Navy awarded Boeing a new F/A-18E/F and EA-18G multi-year procurement contract for 124 aircraft that will be delivered from 2012-2015. The contract includes 66 Super Hornets and 58 F/A-18G Growlers and illustrates the U.S. Navy's extended commitment to Super Hornets in the fleet. In anticipation of growing international interest in the Super Hornet following the U.S. Navy's new multi-year contract and the initial sale of 24 F/A-18F Super Hornets to Australia in 2007, Boeing unveiled a new F/A-18 Super Hornet International Road Map at the Farnborough International Air Show in 2010. The new international configuration offers several upgraded capability options outside the U.S. Navy F/A-18 program of record including Enhanced Performance Engines (EPE), spherical missile/laser warning systems, an enclosed weapons pod, larger conformal fuel tanks, an internal IRST, and next generation avionics.[65] The new F/A-18 international configuration provides both updated technology and a high level of commonality with the successful F/A-18 E/F Super Hornet platform.

In addition to the F/A-18, Boeing is developing a new Silent Eagle international configuration for the F-15. The F-15 Silent Eagle will offer low observable attributes, AESA radar, and reconfigurable conformal weapons bay with internal weapons carriage, digital electronic warfare system, and next generation avionics.[66] Silent Eagle "was specifically designed in response to international customers need for an aircraft with an increased measure of radar-evading capability without the tradeoffs of reduced range and heavy payloads."[67]

The Lockheed Martin F-16 Fighting Falcon is a successful international program, still in production for international customers, and competes for major new FMS contracts. "Lockheed Martin continues to develop the F-16 for the future by integrating advanced technologies through upgrade programs for existing F-16s to ensure interoperability with the world's only 5th Generation fighters, the F-22 Raptor and F-35 Lightning II."[68]

Strike fighter FMS is an attractive option because it reduces the level of additional U.S. government investment in advanced project design teams, provides appropriate capability on the international market desired by our regional commanders, allies and partners, reduces foreign trade imbalance, and boosts the U.S. industrial base. U.S. strike fighter international sales warrants strong government advocacy, however, to compete against aggressive marketing by nationally supported competitors such as Saab Gripen and EADS Eurofighter. The Department of Commerce Advocacy Center plays an influential role in supporting U.S. companies competing for foreign contracts and it could justifiably increase its emphasis on more actively advocating for U.S. platforms in international strike fighter export markets. The international strike fighter market is highly competitive and resource intensive to support requirements such as proposal preparation and in-country field evaluation trials.

FMS should not solely exist for industrial base concerns, however. Strike fighter FMS must have compelling justification from a national security perspective. In many cases, the justification in supporting our national security strategy is clear. Strike fighter FMS involving multiple U.S. prime contractors also provides a secondary benefit of acting as a bridge to sustaining healthy competition in the U.S. strike fighter market. Reuters, in quoting Richard Aboulafia of the Teal Group, reported the U.S. Air Force solicitation on 3 Nov 2010 to industry

for a successor to the F-22 "suggests that Boeing might be able to stay in the fighter business long enough to compete for it…assuming exports can keep its fighter know-how alive as the U.S. Air Force, Navy, and Marine Corps buy F-35s in large numbers."[69] Reuters also reported Aboulafia believes "in short, they (Boeing) might not be forced to abandon this market"[70] In summary, strike fighter FMS could become a key component in helping to sustain competition in the domestic market for the next generation strike fighter competition.

A fiscally attractive companion to U.S. government funding advanced corporate R&D project teams in maintaining design and development teams in the U.S. strike fighter market is to leverage international sales to extend current production runs of fourth generation and fourth-plus generation U.S. strike fighters such as updated F-15, F-16, and F/A-18 configurations. These programs are low risk and high value to the industrial base. There is significant market potential for Foreign Military Sales or Direct Commercial Sales to foreign customers of fourth-plus generation F-15 Silent Eagle, F-16 International, and International F/A-18 configurations. Each of these fourth-plus generation platforms provides greater options and configuration flexibility than export of the current corresponding Programs of Record for the U.S. Air Force and U.S. Navy. These platforms offer highly desired new technology insertion and customized solutions, yet remain below thresholds of fifth generation technology level. As the U.S. begins transition to a fifth-generation strike fighter force, international sales and technology transfer of slightly less capable fourth-plus generation fighter aircraft should receive greater support inside the U.S. government.

The technology transfer process does not only serve U.S. manufacturers. "DoD's processes to evaluate the merits and impact of the international transfer of U.S. munitions and technology calls for the Joint Chiefs of Staff (JCS) to coordinate with the Geographic Combatant Commanders (GCCs) to represent the operational interest and perspectives of the war fighter in interagency processes."[71] The desires of the U.S. war fighter and operational commanders yearning for greater interoperability and allied capability are critically important in weighing technology transfer decisions. There are other emerging threats to US competitiveness and innovation in the aircraft industry structure. Aging of the American aircraft workforce, increasing global outsourcing and industrial participation, and the dearth of new aerospace engineers entering the industry all inhibit U.S. competitiveness. The U.S. will need to effect improvements in education and provide incentives for young engineers to pursuer careers in aerospace. Maintaining a viable defense aerospace work force is of great concern. "The number of workers in aerospace and defense is down from more than 1,000,000 in 1991 to just over 600,000 two decades later."[72] Strike fighter design and development competency is an even more acute concern. A 1992 RAND study expressed "concern that the declining experience base of aircraft design teams poses a serious threat to U.S. Defense capability."[73] Fourth-plus generation F-15, F-16, and F/A-18 FMS can sustain production and modification lines and has some small engineering design and development benefits for manufacturers but will not provide nearly as high level of future engineering design and development work for industry as new strike fighter procurement.

Maintaining critical depth in engineering design and development expertise for the next generation strike fighter will rely on major new domestic aircraft programs on the near horizon such as the U.S. Navy's Unmanned Combat Air System (UCAS) and Unmanned Carrier-Launched Surveillance and Strike (UCLASS) system. The Naval Air Systems Command issued a solicitation for UCLASS proposals on 28 March 2011 with a response date of 29 April 2011.[74] This significant step signals the U.S. Navy's intentions to proceed with an unmanned carrier-

launched persistent surveillance and precision strike platform for operational employment by 2018. These domestic competitions will provide new capability to the U.S. Navy and offer an extremely significant opportunity for major prime military aircraft competitors to continue exercising their critical engineering design and development teams. Mature current production lines do not substantially exercise engineering design competency. "In the main, engineers involved in production and post-production activities represent skills and capabilities different from those of engineers in pre EMD and EMD activities; few transfers occur between such staffs."[75] In assessing the UCAS and UCLASS potential competitors, Aviation Week and Space Technology reported, "Northrop is expected to build off of its X-45B experience, Boeing will use its X-45-based Phantom Ray background and General Atomics will likely use its Avenger concept as a departure for its design. Lockheed Martin is also likely to bid, building off of work on the Polecat demonstrator and the RQ-170."[76] Aircraft manufacturers can bridge engineering design and development expertise from UCAS and UCLASS to later U.S. Navy Next Generation Air Dominance (NGAD) and U.S. Air Force Next Generation TACAIR successors to F/A-18 and JSF. Both UCAS and UCLASS have significant industrial base implications in sustaining competitive aircraft design and development competency.

Section 845 agreements (Section 845 of P.L 103-160) previously used in the Harpoon missile, Global Hawk, the Evolved Expendable Launch Vehicle programs and others, provided authority for DoD to use Other Transactions to improve affordability, increase competition, and achieve greater performance in weapons systems acquisition. Section 845 agreements provided investment incentives for industry and reduced risk. "For example, recognizing their common interest in developing more affordable composite engine components, General Electric and Pratt & Whitney agreed to collaborate with material suppliers on a $32 million project."[77] The General Accounting Office reports, "according to Air Force officials, there was better information flow and greater technical progress using this joint approach than if each firm had undertaken the project separately."[78] DoD and its Defense Advanced Research Projects Agency (DARPA) can use Section 845 type of agreements for competitors to innovate and develop promising technologies for rapid insertion into the next sixth generation strike fighter.

There are significant implications of further development of Remotely Piloted Aircraft (RPA) as potential platforms in a future U.S. next generation strike fighter. It is possible technology in unmanned aircraft will mature quickly enough to replace manned aircraft in our next generation strike fighter. Traditional strike fighter manufacturers will face new competitors as barriers to entry in an unmanned strike fighter market evolve differently than the manned market. Major RPA manufacturers possess aircraft integration competency allowing them to compete for future unmanned aircraft programs. Companies with mature long-endurance unmanned air vehicle systems have a key core competency needed in a competition for a potential unmanned next generation strike fighter. In particular, the U.S. Navy UCAS will serve as a significant launch platform for subsequent unmanned next generation strike fighter technology. Major strike fighter manufacturers may today be investing in RPA technologies partly as a hedge to position themselves more competitively against traditional major RPA manufacturers should the next generation strike fighter become an unmanned platform.

Conclusions and Policy Recommendations

By focusing on the impacts of the USAF tanker deal and the success of the Joint Strike Fighter on their relevant markets, the seminar found changing dynamics and systems in the way that aircraft manufacturing, procurement and competition interact. These changes have been in the areas of defense trade linkage, procurement as part of an industrial policy and in the use of an industrial policy as part of a larger defense, economic, or security strategy. While these three areas build upon each other, the changing defense trade linkages represent the most important facet. Trade and defense, especially defense research, procurement, manufacturing and international sales, have always been linked since the rise of mercantilist policies and the development of industrial production facilities. Today, these linkages have only increased in importance and will ultimately dominate market priorities to a greater extent than cost or functional requirements.

The requirement to develop and produce arms has always had an aspect beyond meeting military requirements. The domestic impact of wealth and job creation, within the associated social compact, and the need to care for, train for, and support these jobs, significantly influence each procurement decision. The choices to gain these non defense benefits domestically and decisions on the transfer of technologies and production capabilities overseas has *de facto* led to a system of government controlled, or at least significantly influenced, production and the creation of national champions. Initially, mechanisms developed to balance and control this trade were through the use of subsidies, production offsets to gain orders, and rules governing competition and technology transfers. However, spiraling aircraft costs, shrinking defense budgets and smaller, less frequent program starts are now pressurizing these old rules of the game.

Subsidies were the bedrock of protecting national champions and thus maintaining a sovereign capability for independent production and for gaining direct domestic economic and spillover benefits. They took many forms, including preferential financing of capital, research and development grants, land grants, tax breaks and government incentives to investment by third parties. Subsidies could be direct as stated or indirect such as defense research investments that produced spillover technologies to a company's commercial production. The most contentious of subsidies were in the commercial aircraft market which led to the duopoly in large commercial aircraft and the duopoly in regional jets. In both market segments there have been multiple World Trade Organization (WTO) cases with many rulings against subsidies that ultimately have been resolved by governmental agreements on limiting subsidies to maintain a level of parity between parties. With such focus placed on subsidies, the trend moving forward is in a reduction of domestic subsidies and a heavier focus on governmental assistance to generate more international sales for several reasons. The first is that domestic budgets and rising social and debt costs have made direct subsides less affordable politically for governments. The second is that domestic defense markets are no longer large enough to support subsidized production without international sales of aircraft. The third is the previously stated WTO rulings against subsidies.

In addition to direct and indirect subsides, sales assistance internationally traditionally has been in the form of offsets. The Bureau of Industry and Security (BIS) defines offsets as "mandatory compensations required by foreign governments when purchasing weapon systems and services."[79] Offsets have been used for many years to promote products, encourage procurement, and reward buyers of aircraft in the commercial and military markets. While

mostly these offsets have taken form as a portion of work share, component production, or final assembly, they also can occur in a completely unrelated industry. Today, however, offsets are diminishing in stand alone importance due to two factors. The addition of rules and guidelines in supranational bodies such as the European Union (EU) and the WTO have made offsets harder to emplace legally. Secondly, while job share is important, nations with growing economies are increasingly interested in developing their own strategic industrial base. As such, former simple offset agreements are morphing into technology transfer deals and the demand for true partnership as equals. To quote a senior European aerospace executive, "offsets are so nineties."[80]

Technology transfer, both in the form of intellectual property and production partnering and training, will be a major driver for future international aircraft sales. Emerging nations desire more than the receipt of a commodity. They desire the economic benefits and spin offs from high tech industries, which include the creation of high value jobs, a sovereign capacity to develop a strategic industrial base, and ultimately a stepping stone to a future competitive entry into international markets. As such, governments that have more open technology transfer policies will be able to provide greater support to their industries in sealing foreign sales. The U.S. ITAR policies are restrictive in this matter and there is speculation that the Indian fighter competition was won or lost as much on technology transfer issues as on the strengths and weaknesses of the aircraft involved.

With the assumption that the current threat environment does not change, competition in these critical markets will more and more be determined by externalities to deals that are part of the larger defense trade linkage. While price point and capability will remain important factors, the political support provided by governments and the extent to which global partnerships are forged will greatly determine future growth opportunities. To nations which lack sufficient domestic market size to sustain strategic sectors, such growth opportunities are critical to the maintenance of their standard of living and to maintaining strategic relevance. To nations which possess the capacity to domestically support strategic industries, these opportunities can make domestic support more affordable, thereby diluting risk and providing opportunities to increase investment in additional areas of concern.

At times, these new global realities will contravene domestic political priorities. But while domestic politics will always play a heavy role in procurement and budget decisions, without clear national priorities and a functioning strategic industrial policy, the protection of domestic production may undercut future international competitiveness. Moving forward, industries and governments must both recognize that strategic procurement is *de facto* an industrial policy. And a nation's industrial policy must address the ability to meet strategic requirements in terms of capacity to sustainably produce while also meeting any required social demands.

The political decision to produce additional C-17s or the recently suspended fight to produce an alternate engine for the JSF are examples of such a *de facto* policy. In such cases, a policy has been created to subsidize local economies through spending not demanded by military requirements. The other similar but subtly different policy is to invest in research and development or low rate production to keep a certain set of skills or capabilities within a national industrial base. A policy of promoting international sales can achieve the same result while lessening the costs imposed on the domestic defense budget. Furthermore, if planned correctly, benefits such as spin offs will result which can greatly expand the societal benefits of strategic procurement.

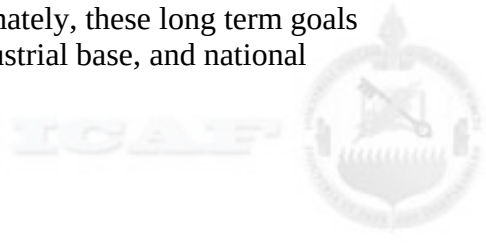
Spin offs are the secondary and tertiary, non direct economic benefits of high tech defense and aerospace industrial production. They include advances in basic research, movement of skilled labor and engineers to other sectors of the economy, and the creation of new industries and capabilities through implementation of dual use and military developed technologies. The development of required supporting industries, training and education, and research capabilities is also a spin off effect. While these support structures can occur without a policy, some countries have industrial policies that drive and sustain procurement in identified key areas in order to gain spin off benefits beyond the preservation of a particular strategic capability. Sweden, for example, has identified that it will protect submarine and fighter production as key economic drivers in order to spin off of other economically desirable high tech industries.[81]

Industrial and procurement policies can also have very large impacts on the market, either indirectly or as part of a deliberately planned effect. The JSF program and tanker competition are both examples of this. In the JSF program, the prevention of the emergence of a next generation European fighter and the weakening of the European ability to sustain such production through internal markets can be seen both ways. While there is no stated U.S. industrial policy that the JSF program was designed to have such an effect, some European observers view the program as a deliberate attempt to slow, weaken and possibly eliminate the ability for Europe to indigenously produce such a fighter.[82] Alternatively, the tanker competition had an industrial procurement policy of using competition for the tender in order to drive down price. The effects of this policy may result in retaliatory moves against U.S. businesses abroad (if the tanker competition was not seen as a real and fair competition) or in an increase of investment in the U.S. by foreign companies in order to compete in future DoD procurements. Either way, the outcome of the next competition could prove if the United States is merely using the threat of a foreign competition to lower domestic prices or if real competition exists in the U.S. market.

In addition to the above procurement ramifications, a viable industrial procurement strategy is critical to building new and stronger relationships among trading partners. Previously, a bilateral dependency between buyer and producer was sufficient to bring a nation under one's security umbrella. Today, current growth markets are challenging this paradigm by forging strategic partnerships seeking a more equal representation. And as a byproduct of a globalization and recent financial trends, the ability to make purchasing decisions free of any cold war bias allows growth markets to rapidly build a strategic web of partners by pursuing aerospace and other strategic articles.

The changing paradigm and overall effect of technology transfers will potentially increase the competition from such emerging markets and reduce the U.S. relative lead in such technologies. As such, a carefully managed industrial procurement policy must specifically prioritize and protect those areas which must be maintained while increasing access to those that will improve U.S. competiveness abroad. Ultimately, the willingness to transfer technology will secure more deals thereby protecting critical domestic industries. However, at the same time, a policy that shares technology to support domestic industries must also foster innovation to maintain a relative competitive advantage.

In order to secure the international sales that are so critical to maintaining viable domestic industries, any policy, stated or unstated, must focus on gaining strategic leverage with those whom this nation conducts business. When properly prioritized, both buyers and competing sellers act in strategic ways to achieve their long term goals. Ultimately, these long term goals must balance the priorities of economic vitality, an innovative industrial base, and national



security requirements, all while meeting the political demands of the existing social construct. In order to support these competing demands over the long term, the U.S. needs to develop goals and strategies that drive a supporting industrial procurement policy.

Policy Recommendations

1) Fund contracts for advanced corporate R&D project teams: The government can perform a role in addressing the engineering design and development resource gap. Funding contracts for advanced corporate R&D project teams are an option for maintaining competition in the strike fighter market. The argument for government investment in competitive research and prototype development teams for a next generation manned strike fighter is compelling from innovation, risk mitigation, and affordability perspectives. The government will benefit from multiple domestic prime manufacturers competing in the strike fighter market. Funding design and R&D teams to compete for next generation strike fighter aircraft development could prove a cost effective and innovation-spurring acquisition strategy even with significant up front DoD investment. "Funding multiple technology developments, advanced design studies and demonstrator aircraft programs, preserves critical elements of industry design and development capability, supports innovation, creates opportunity to develop and demonstrate transformational system concepts, and enables competition in design for next weapon system."[83] DoD could encourage joint ventures in the two competing teams to reduce individual corporate risk exposure and provide additional corporate technological competence and talent for innovation to each team.

2) Improve government-industry dialogue in technology road map sharing: The U.S. Air Force uses a three-step process for optimizing IR&D alignment with industry and serves as a useful model for wider government-industry IR&D information and road map sharing. Broader and more transparent technology road map sharing lead by AT&L should optimize both DoD and corporate IR&D investment in the key technologies for the next generation of strike fighters to follow JSF and F-22.[84]

3) Leverage Foreign Military Sales (FMS) with a more competitive export control policy: Strike fighter FMS with multiple U.S. manufacturers could ensure the future domestic strike fighter competition is not ceded to a single aircraft manufacturer. If Boeing and Lockheed Martin were able to extend current production runs of F-15, F/A-18 and F-16 with small engineering design efforts tailored to meet unique FMS customer technology needs, they could preserve a minimal level of perishable engineering design and development competence and have the competence to competitively bid on a next generation strike fighter.

The U.S. could change export control policy to promote global competitiveness in the military aircraft industry. Defense Trade Cooperation Treaties are effective mechanisms for streamlining exports and facilitating faster transactions for existing FMS fighter programs but are less suitable for competing more effectively in new aircraft competitions. Easing of technology transfer restrictions that reduce the attractiveness of U.S. military aircraft in general and strike fighter platforms in particular, such as the F-15 Silent Eagle, F-16 Fighting Falcon, and International F/A-18 Super Hornet, could significantly increase likelihood of success in major international sales competitions in Brazil, India, Japan, and others. In these competitions,

industrial participation by the procuring nation is a major factor in contract award. Cumbersome, time consuming, and restrictive technology transfer limits on U.S. manufacturers effecting industrial participation place them at a competitive disadvantage against international competitors. The Defense Security Cooperation Agency (DSCA) acknowledges, "technology transfer decisions have many moving parts – 3 committees, 15 processes, 23 agencies involving 45 separate offices. Each functions under unique guidance and often with an agenda. No single office is responsible for the U.S. Government (USG) position. The process is generally reactive and slow."[85] Technology transfer approval delays invite our international competitors to exploit our inflexibility and gain a competitive edge in reliably offering comparable technologies with far quicker response times. An opportunity arises today for appropriate technology transfer policy to stimulate international sales of fourth-plus generation strike fighters to countries not eligible for or desiring of the fifth-generation F-35. Facilitating highly affordable U.S. fourth-plus generation strike fighter FMS can be an effective strategy for deterring customers away from procurement of comparable technology from our international competitors. The rich benefits of a major FMS program in establishing closer long-term military-military relationships and expanding interoperability are then ceded to our international strike fighter competitors. Reforming and streamlining appropriate export control and technology transfer policies with suitable risk assessment and flexibility in choosing levels of transfer should increase U.S. strike fighter competitiveness internationally and reflect front line war fighter desire for allied and partner nation strike fighter capability and interoperability. Formal government advocacy plays a decisive role in major international strike fighter competitions.

4) Prioritize and recognize new UAS programs importance in sustaining critical aerospace engineering design and development skills: FMS will only partially address sustaining critical engineering design and development. Transitional and bridging aircraft design programs, such as UCAS and UCLASS, offer immensely high value since they should provide timely engineering design and development work for manufacturers hoping to sustain a dwindling aerospace work force to compete for the next generation strike fighter aircraft in the 2030 time period. European nations recognize this need for sustaining critical engineering design and development skills with their Taranis and Neuron unmanned demonstrators. Should FMS and aircraft design bridging programs not fully materialize in the near term, the U.S. government will face a shortage of vital current engineering expertise and will need to invest billions and wait years to replace it.

5) Sustain funding for research and development of manned or unmanned next generation strike fighter: The U.S. Air Force Next Generation Tactical Aircraft and U.S. Navy Next Generation Air Dominance programs are on the horizon. Delays in these programs could require more than FMS and aircraft design bridging programs to ensure the U.S. has the resident industrial design and development expertise to innovate with new technologies and build the next generation of strike fighter aircraft.

APPENDIX 1 – LARGE COMMERCIAL AIRCRAFT

Firm	Description	Strategy	Political Environment	Market Preference	Cash Flow	Likely Action
Boeing	Boeing is known for commercial planes, but its Defense, Space & Security (BDS) unit (formerly Integrated Defense Systems) accounts for approximately 50% of the profits. The Department of Defense (DoD) accounts for about 80% of BDS sales.[86]	Two poles are likely as Boeing moves forward. The first is to defend the U.S. DoD market at all costs. This has been done more through teaming with other partners The other strategy Boeing must follow is access to the international marketplace.	Boeing is the last remaining U.S. national champion for commercial aircraft presenting itself as the defender of U.S. jobs. Boeing receives strong domestic support and incentives from state and city governments where it bases production.	Based on a model of cost savings on fuel efficiency and the ability to open up more direct city pairs, is central to how Boeing sees the market. The looming market issue for Boeing is the 737 replacement aircraft.	Heavy debt burden. Cash flow expected to improve with the 787 deliveries starting and the US tanker award.	Boeing has not opened any final assembly or full production lines overseas and with an upcoming cash flow this could be an opportunity for an overseas acquisition or investment. Boeing will have to decide whether to re-engine or re-invent its single aisle champion.
EADS AIRBUS	Firm Summary European Aeronautic Defence and Space Company (EADS) is an international marriage of moguls: Daimler Aerospace (DASA, Germany), Aerospatiale Matra (France), and Construcciones Aeronáuticas SA (CASA, Spain). The group is Europe's largest supplier of aerospace, defense and related services. [87]	EADS was betting on an entry into the US defense market for EADS (North America) to establish itself politically as a U.S. defense prime contractor. This would also have opened up a commercial production line in the US permitting hedging against dollar euro rates in global production.	Born from previously state run enterprises with large social considerations (employment protection) the ties with European governments are close. This has worked to EADS advantage in generous capital In the negative role the close government ties mat restricts EADS	EADS/AIRBUS has invested in a model of airlines moving large amount of passengers from hub to hub. They are developing an A350 model to compete with Boeing in the long range point to point efficient market.	Flush with cash (an estimated 11.3 billion dollars)	Speculation exists that EADS will acquire vertically in the European market or in the US to establish itself for a future US DoD acquisition programs A320 aircraft are already produced at an EADS plant in China so they are basing production offshore to gain market access as an existing strategy
Embraer	Brazilian aviation company makes commercial jets (37-122 seats). Its defense aircraft and systems division manufactures light attack, trainer, and surveillance aircraft for military markets,	Embraer sees the largest growth in the regional jet market to be in the 90-120 seat range and has its eyes on capturing as much of that market as possible around the world.[88]	Embraer was privatized in 1994. In a national environment that openly supported science and business through state intervention and protection there remained a very cozy government/ industry partnership.[89]	Embraer has not shown any strategic intentions to move into a larger category of jets. However it has an international partnership in China to produce the older ERJ line of regional jets.[90]	Embraer had significant positive cash generation during 4Q10 and the Company's Net cash position for the period increased by US$ 74.3 million achieving US$ 691.8 million.[91]	The main focus of company strategic outlook documents is capturing the largest market share internationally of the key segment (90-120).
Bombardier	Bombardier Aerospace is the division of Bombardier which makes business jets CRJ regional jets and Q Series Turboprops and amphibious aircraft. Its big jet C Series commercial aircraft that will seat up to 149 people are scheduled to go into production by 2013.[92]	Bombardier is betting its farm on the C series very large regional to small single aisle size family. This 110 to 130 seat size market is where they see a building demand, an aging fleet and ignoring of the market by the two large commercial jet players	The Canadian government seems to be willing to let market forces work.[93] The nature of political interaction seems more to be a poker type of play for concessions and not a client patronage type relationship.[94]	The low end single aisle market has been underserved in new technology and is an opening. The company is hoping to leverage this entry into a single fleet sales pitch for the 90-120 size jets.		Price is where they are competing with the big boys.[95] Bombardier is also "partnering "with Chinese aircraft manufacturer COMAC.[96] This seems to be a way to share suppliers and a strategy to keep COMAC out of the smaller jets and to gain favorable Chinese market.

Table 1 Comparative Analysis of Large Commercial Aircraft Firms

Technology Readiness Level	Description

1. Basic principles observed and reported.	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development. Examples might include paper studies of a technology's basic properties.
2. Technology concept and/or application formulated.	Invention begins. Once basic principles are observed, practical applications can be invented. The application is speculative and there is no proof or detailed analysis to support the assumption. Examples are still limited to paper studies.
3. Analytical and experimental critical function and/or characteristic proof of concept.	Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.
4. Component and/or breadboard validation in laboratory environment.	Basic technological components are integrated to establish that the pieces will work together. This is relatively "low fidelity" compared to the eventual system. Examples include integration of "ad hoc" hardware in a laboratory.
5. Component and/or breadboard validation in a relevant environment.	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonable realistic supporting elements so that the technology can be tested in a simulated environment. Examples include "high fidelity" laboratory integration of components.
6. System/subsystem model or prototype demonstration in an operation environment.	Representative model or prototype system, which is well beyond the breadboard tested for TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high fidelity laboratory environment or in simulated operational environment.
7. System prototype demonstration in an operational environment.	Prototype near or at planned operational system. Represents a major step up from TRL 6, requiring the demonstration of an actual system prototype in an operational environment, such as in an aircraft, vehicle, or space. Examples include testing the prototype in a test bed aircraft.
8. Actual system competed and "flight qualified" through test and demonstration.	Technology has been proven to work in its final form and under expected conditions. In almost all cases this TRL represents the end of true system development. Examples include developmental test and evaluation of the system and in its intended weapon system to determine if it meets design specifications.
9. Actual system flight proven through successful mission operations.	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation. In almost all cases, this is the end of the last "bug fixing" aspects of true system development. Examples include using the system under operational mission conditions.

Table 2 NASA Technology Readiness Levels

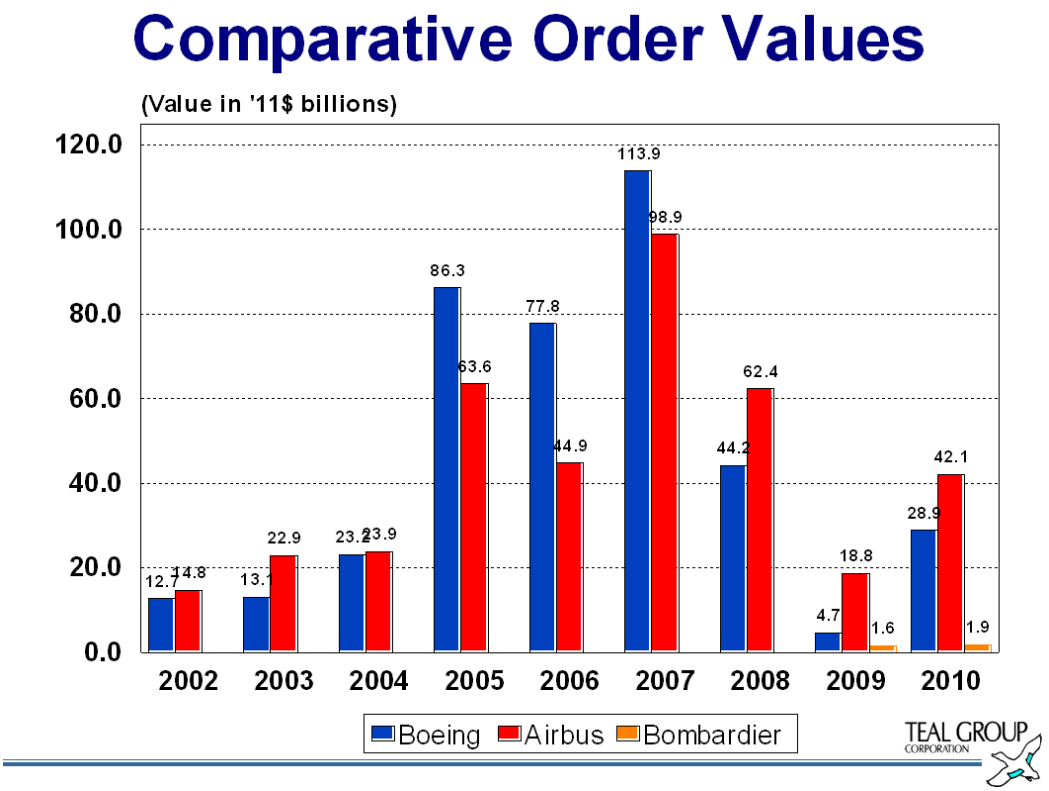


Figure 1 Historical Market Share
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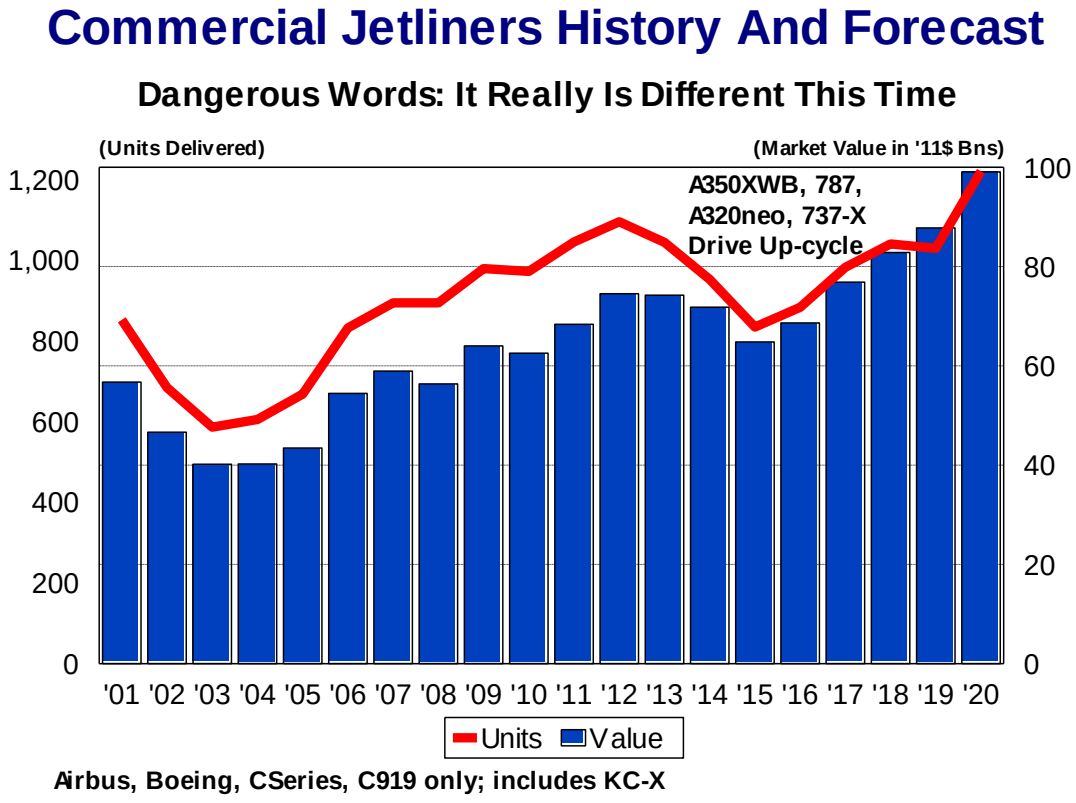

Figure 2 Projected LCA Market Growth
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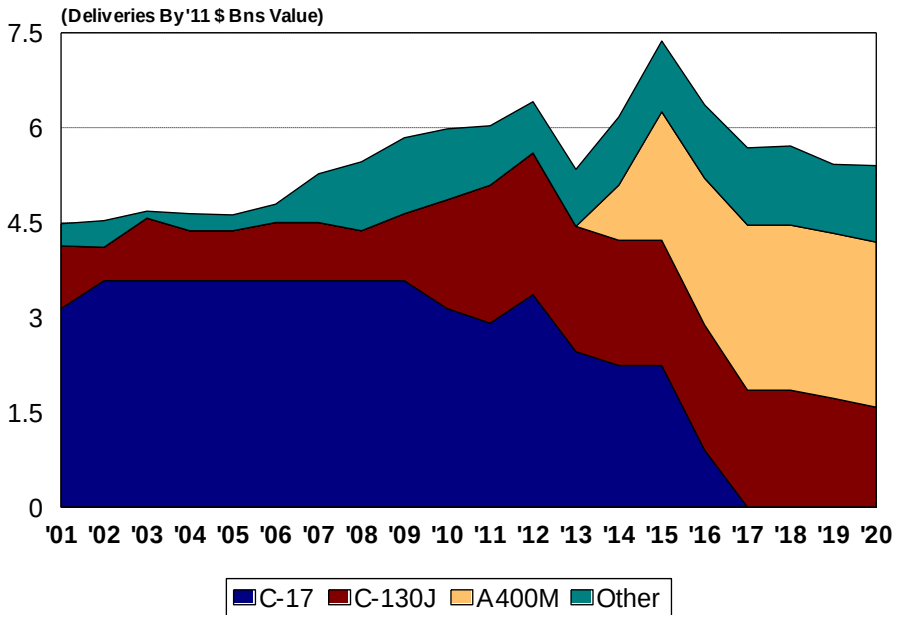

Figure 3 Military Transport Market Projections
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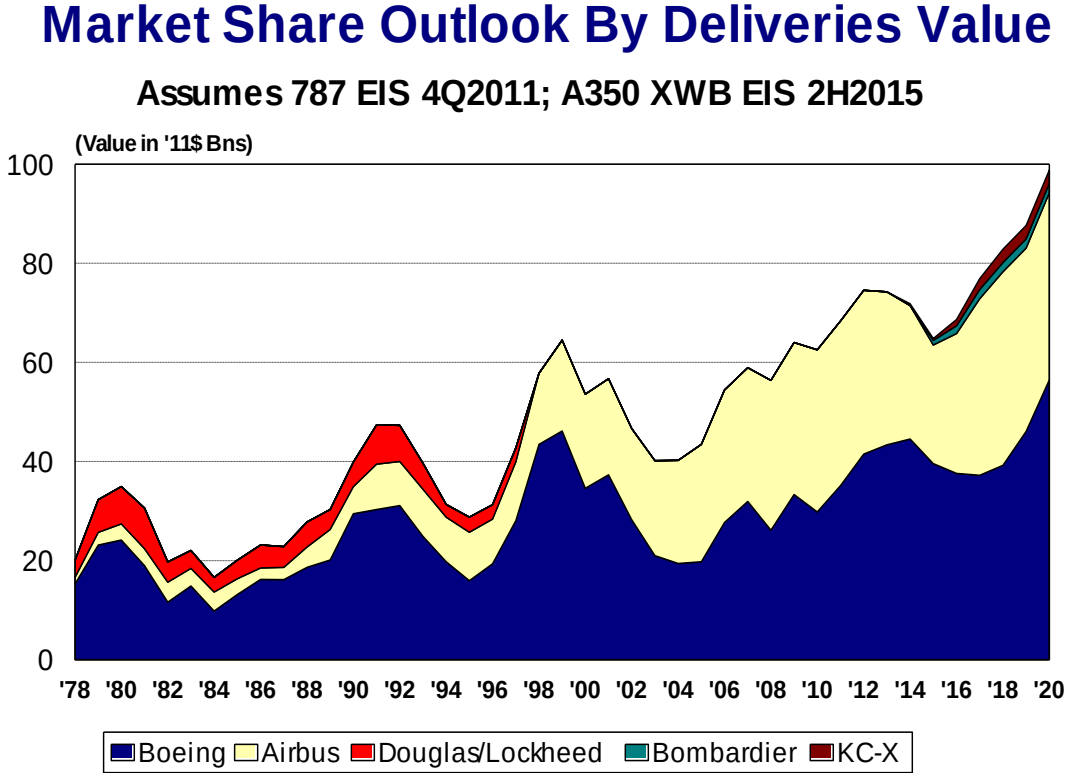

Figure 4 Market Share by Deliveries
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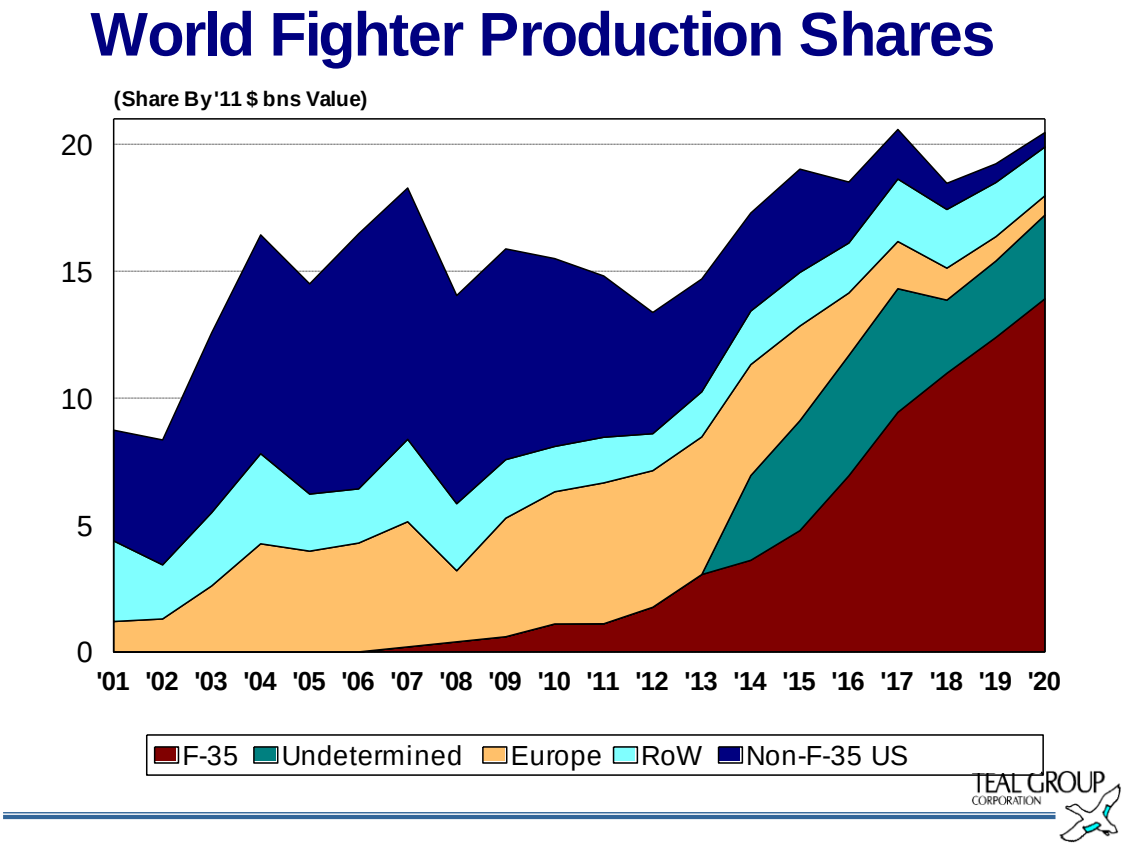

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Fighter Aircraft Market Dynamics in Asia

The fighter market is growing in Asia, **primarily because of rising wealth and concerns over the Chinese military's modernization efforts.**

China itself is not yet at the point where it can build fighters that are competitive with the best the West has to offer, with engine development being a major stumbling block. Chengdu has developed the FC-1 lightweight fighter for the export market and the multi role J-10 for China's own needs. Both are relatively low-cost single-engine modern fighters that are a little behind the latest versions of the F-16 and Gripen. But China is acquiring large numbers of J-10s and has developed the J-11, its own improved version of the Su-27. A large stealthy fighter, the J-20, entered flight test in January, but when it will enter service is not known.

Add into the mix an unpredictable **North Korea,** and **Indonesia's** interest in growing its fleet of Su-27/-30s to 180 aircraft, and the result is a number of nations seeing a threat and looking to replace aging models with newer aircraft with the latest in sensors and weapons.

South Korea and **Singapore** are both building fleets of F-15s. **Japan** is interested in the F-35, F/a-18 E/F, and Eurofighter to replace its fleet of aging F-4EJs under its F-X program. The Japanese government wanted the F-22 to fill the requirement, but the Raptor cannot be exported without a change in U.S. law. The refusal to sell the Raptor led the Japanese to flirt with Eurofighter and examine the possibility of developing its own stealthy aircraft.

F-35 Joint Strike Fighter Market Potential in Asia

According to Lockheed assessment, the potential market in Asia for the F-35 Joint Strike Fighter (JSF) could be more than 500 fighters in the next two decades, with Japan, Singapore, South Korea and Taiwan paying the closest attention. Though there have been problems in the F-35 program over the past year, interest in Asia in a stealthy fifth-generation fighter has not dampened.

Singapore's Air Force: Sources indicate Singapore's Air Force could procure up to 100 fighters to replace its roughly 60 F-16C/Ds beginning in 2020. Singapore has shown determination to stay ahead of the game regionally, in terms of having a more modern and more capable air force than its Southeast Asian neighbors.[97] Some of Singapore's neighbors, such as Indonesia and Malaysia, might object to the F-35 procurement depending on the state of their relations with Singapore.

Japan: Japan has a requirement for 200 to 250 fighters for the F-XX competition set to begin in 2020.With respect to both Japan and South Korea; Lockheed Martin fully supports each country's fighter fleet recapitalization efforts through full and open competitions. However, Japan began working on a stealthy, indigenous fifth-generation fighter program last year. The Advanced Technology Demonstrator-X (ATD-X) is a $500 million study being conducted by the International Public Affairs Office under Japan's Ministry of Defense (MoD). Dubbed the Shinshin stealth fighter, the MoD has indicated that only preliminary research has been conducted so far. The ATD-X is part of Japan's three-pronged approach to strengthening its air power, which for the short term is based on improving air-to-air combat and self-defense capabilities of its present stock of F-2 and F-15 fighters, while a request for proposals to replace

aging F-4s is expected later this year, according to sources. In terms of strengthening the combat capability of its fighter fleet, Japan is equipping the F-2 with self-guided air-to-air AAM-4 missiles and upgrading the fighters' radars. Meanwhile, its fleet of F-15s is getting an integrated electronic warfare system with upgrades to the radar jamming equipment, a radar warning system and a countermeasures dispenser system, according to MOD documents.

South Korea: South Korea also has expressed interest in the F-35, which often has been referred to as a front-runner by military officials for South Korea's F-X III program for 40 to 60 fighter aircraft. Seoul views advanced fighter buildups in both China and Japan with concern, as well as the threat posed by its traditional enemy, North Korea. South Korean defense industry sources have indicated delivery of the F-35 conventional takeoff and landing variant could be made as early as 2014 if a contract is sealed by 2011, but a series of cost overruns and delays related to the F-35 international development program casts doubts on whether Lockheed could deliver with in this timetable.

Taiwan: Taiwan defense officials have openly expressed an interest in the F-35 as a replacement for aging fighters. At present, Taiwan has roughly 60 F-5s and 60 Mirage 2000-5s scheduled for retirement within the next 10 years. Since 2006, the U.S. government has refused Taiwan's letter of request to buy 66 F-16C/D fighters. Part of the reason has to do with increased diplomatic and economic pressure from Beijing.

Asian Fighter Market Analysis

In Asia, **Lockheed Martin** is pursing its **F-35**, the only fifth-generation fighter available for export. Western manufacturers such as Boeing and Lockheed Martin from the USA, France's Dassault, the Euro fighter consortium and Sweden's Saab are vying for several potentially lucrative contracts around the region. They face stiff competition from the Russian alternatives, which will take advantage of Moscow's long-standing political and military relationships. China, too, is fast emerging as a viable alternative supplier. What, however, do the various air forces really need? While there is a lot of talk about fourth- and fifth-generation fighters, these labels are of little help in understanding the actual requirements of the various countries. It is far better, say observers, to talk about the capabilities that are available and link them to national requirements.

Lockheed, which is pushing both its latest version of the **F-16 Eagle** single-engine multi-role fighter and the **F-35 Joint Strike Fighter**, the only fifth-generation aircraft available for export, believes that having situational awareness and denying it to adversaries will be increasingly important. “Through stealth, electro-optical sensors, powerful and advanced active electronically scanned array radar, electronic warfare, inherent jamming capability, and the ability to share information via secure data links, the F-35 combines its sensor capability like no other platform before it.”[98] It's difficult to remove the platform from the equation, because the platform itself is integral to the capability. Lockheed, reflecting the fact that its products are primarily for allies of the USA, adds that threat perceptions matter. Lockheed thinks that given the continued increase in capability - and numbers - of fighters being developed by China and Russia, it becomes imperative that regional governments continue to equip their air forces with the leading edge capabilities required to counter the emerging threats to security.

APPENDIX 2 – FIGHTER MARKET AND SALES

Boeing is promoting its **F/A-18E/F International Super Hornet** and **F-15 Silent Eagle** multi-role fighters actively in the Asia-Pacific region. It also believes that platforms are the key. Boeing thinks there will be continued fusion and integration of on-board and off-board sensors and weapons, giving pilots the ability to detect and engage targets in any domain - in the air, at sea, or on the ground. Boeing argues that multi-role capability is paramount for countries investing in fighters. Fighters don't just exist in one or two spectrums any more. They must be able to fulfill a variety of missions over vast geographic space. These aircraft will handle both strategic and tactical missions, including air-to-air, maritime strike, air-to-ground, and ISR missions. Long endurance and versatility will always be factors in Asia Pacific, given the vast geographic diversity - over water, over mountain ranges, and other terrain.

Russia has been a main stay in Asia for decades. **Rosoboronexport**, the country's arms export agency, is promoting its Sukhoi Su-30, Su-35 and RSK MiG-35 as replacements for earlier aircraft such as the Su-27, MiG-29 and MiG-21. Russian export agencies think that they "have many close friends in Asia - India, China, Malaysia, Indonesia and Vietnam being some of them."[99] While there is more competition from the USA and Europe, but Russians' are confident in their ability to secure more contracts in the coming years.

Representatives from the **EADS** Eurofighter Typhoon consortium and **Dassault** Rafale have been active in the region as well. Neither, however, has had a sale yet. **Saab**, on the other hand, had its first success in Asia Pacific after signing a contract with Thailand for six Gripens. It is pushing Bangkok to buy another six and promoted the fighter in India and Malaysia. Its sales pitch is essentially that its "ideologically neutral" fighter is cheaper than and just as capable as its competitors.

China is becoming more active. Beijing has exported fighters for several decades - most notably the Chengdu F-7 interceptor and Nanchang A-5 ground attack aircraft to the likes of Bangladesh, Myanmar, Pakistan and Sri Lanka. But it has newer-generation fighters and it is now casting its net wider. Beijing has held talks with several countries on the **Chengdu FC-1**, also known as the **JF-17** in the export variant that was developed with **Pakistan**, and the light attack variant of the Hongdu L-15 advanced jet trainer. For JF-17 customers, China could set up an assembly line or produce components for the aircraft, just like some Western suppliers. This includes traditional and non-traditional clients.[100]

The Asian strike fighter market will continue to be the worlds' most active over the next decade, with the countries likely to buy more than 500 aircraft to supplement existing fleets, embark on upgrades and acquire new capabilities to take them into the next stage of their development. For many Asian countries, fourth-generation planes will be useful and relevant for decades to come, and there should be orders for a few more batches of these aircraft.[101]

APPENDIX 3 – India Medium Multi-Role Combat Aircraft (MMRCA) Competition and Lessons

The recent decision in April 2011 by India to down select in their domestic MMRCA competition to two European manufacturers represents a positive development for the West. Down selection to non-Russian manufacturers should reduce Russian influence in India gained from legacy Russian fighter aircraft programs as the winning manufacturer will help establish closer long-term military, political, and economic ties between India and European nations through the MMRCA program. Of note, it will be important for India to also procure common systems with the West for command and control to foster improved operational interoperability. Eventual award of the 126 aircraft MMRCA contract in India will also significantly boost competitiveness of either Dassault's Rafale or EADS' Eurofighter in future international fighter competitions such as in Brazil or Japan. Negative impact of non-selection will be felt most significantly by Saab as the company continues to attempt to find a critically needed launch customer for the Gripen NG. Non-select of MIG-35 will lead to reduced Russian influence in the Indian Air Force and represents another significant milestone in India's move to the West in defense acquisition.

Not down selecting a U.S. strike fighter manufacturer represents a calculated political and economic decision by India. With significant programs already underway with U.S. companies, non-selection of both Boeing's F/A-18 Super Hornet and Lockheed Martin's F-16 in the MMRCA competition might signal a concern for too broad a dependency on U.S. exports of critical defense products. Seen from the Indian perspective, selection of a European manufacturer provides source nation diversity for India's growing portfolio of new major weapons systems. Potential selection of EADS would also optimize opportunity for soliciting voting member support from two countries for accession to the UN Security Council. EADS has already established an extensive industrial participation relationship with HAL in India through its Eurocopter India subsidiary and capitalized on this relationship in the MMRCA competition. Equally important, European manufacturers offering larger technology transfer packages backed by less restrictive national export control policies and extensive industrial participation addressed the critical aspect of winning the deal with India. Technology transfer packages in modern international defense acquisitions must assume a more transparent partnership relationship between the parties vice the outdated seller-customer relationship of the past. One cannot overstate the importance to India of the manufacturer and host country establishing a more transparent technology transfer partnership in the down selection in the India MMRCA competition. It is a lesson to take forward in all considerations of appropriate levels of technology transfer the U.S. should offer in future weapons system competitions. Choosing to not offer a competitive package of U.S. technology opens the door to foreign competitors selling comparable, slightly less comparable, or sometimes even superior technology and reaping the accompanying long-term economic and political benefits of a major weapons system sale. Industries and governments must both recognize that procurement decisions can themselves set industrial policy precedent.

Although MMRCA non-selection might hinder competitive F-18E/F and F/A-16 offerings in future international fighter competitions, Boeing and Lockheed will continue with F/A-18 Super Hornet production in the U.S. Navy's new MYP contract and in F-15, F-16 and JSF production respectively. The greater loss for the U.S. will be in a missed opportunity to expand the overall U.S. and India strategic relationship through a MMRCA program to accompany growing defense procurement ties through ongoing C-130J, C-17, and P-8I acquisitions.

APPENDIX 4 – Strike Fighter Market Firm Analysis

Firm	Description	Strategy	Political Environment	Market Preference	Likely Action
Lockheed	Combat aircraft (72%), air mobility (aircraft system support and sustainment), and other aeronautics (rapid prototype applications). The U.S. government is the company's largest customer Accounting for more than 80% of sales.	Advocates U.S. lead in technology and numbers is diminishing. Reinforced this with the increasing recapitalization requirements. Lobby based on this threat for more funding for DoD strategies that require more of their products. Continue to develop the advanced technologies that DoD cannot refuse and must have to deal with the threats pointed out in line of operation one.	Lockheed became the sole prime for long-term US fighter makers when it won the Joint Strike Fighter (JSF) contract.[102] With the increased time between procurement of fighter systems competitors have little incentive or ability to maintain the engineering and manufacturing capabilities on their own to be a fighter prime long-term.	Lockheed sees the U.S. DoD as the golden customer that will provide the large programs and create the international teams to keep it in the fighter business for a long time. With shrinking defense markets only the U.S. DoD can provide the bulk around which to build economies of scale and production. International sales needed to sustain F-15 and F-16 production lines.	Winning U.S. contracts is critical, so Lockheed invests heavily in bleeding edge technologically intense classified programs to ensure that the U.S. DoD stays a satisfied customer.
Boeing	Boeing F/A-18E/F Super Hornet established as successful and mature program serving as principle USN strike fighter today. USN will operate F/A-18 E/F and EA-18G with JSF through 2030.	F/A-18 E/F Super Hornet capitalizing on success of F/A-18 Hornet program and commonality with Super Hornet. Current USN acute strike fighter shortfall creating need for immediate delivery of additional F/A-18 E/F capability to the fleet. Opportunity for additional USN procurement. Opportunity for International F/A-18 E/F and F-15 Silent Eagle FMS offering customized capability to suit unique customer requirements.	SECDEF touted $5.3B F/A-18 Multiyear Procurement 3 (MYP 3) signed Sep 2010 as an example of cost-savings efforts in Pentagon - saving 10% = $600M. Support in Congress for continuing F/A-18 production line.[103]	Domestic and international sales. USN MYP 3 procuring 124 F/A-18 E/F and EA-18G through FY-13. Australia procuring 24 F/A-18 E/F.	Continue proposing International F/A-18 E/F and F-15 Silent Eagle alternatives for countries seeking a highly capable, stable low cost, low risk platform if JSF not available, JSF schedule delay causes capability gap (Australia), or high level of domestic IP required (Brazil, Japan). Commonality with widely exported F/A-18 Hornet and F-15 Eagle a strong selling point for new F/A-18 E/F Super Hornet and F-15 Silent Eagle.

APPENDIX 4 – Strike Fighter Market Firm Analysis

EADS	Established in 1994, the Eurofighter consortium. EADS' business unit Military Air Systems manages the national work shares in Germany and Spain through the legal entities EADS Deutschland and EADS CASA as the respective Eurofighter Partner Company.	To continue the "*juste retour*" model to attempt to bring in new markets "We will transfer some of our development projects, which we have in Europe for Eurofighter or other military aircraft to India, where we have set up a military research and development (R&D) centre in Bangalore," EADS chief executive (defence & security) Stefan Zoller.[104]	Four nations working through a NATO program office to oversee two divisions. One division produces the plane the other works on the engines. In Eurofighter the work share was based on number of planes ordered and as nations cancelled orders this was renegotiated several times.	More international sales will keep the consortium alive. However this will work to further dilute the work shares and technology transfers.	The Eurofighter Typhoon is unique that there are four separate assembly lines. Each partner company assembles its own national aircraft, but builds the same parts for all 683 aircraft (including exports). A fifth assembly line will be established for the final 48 Saudi aircraft.[105] A next tranche aircraft may be developed depending on the outcome of the Indian fighter competition.
Dassault	Luxury jets account for the bulk of the company's fortunes, Dassault's military aircraft, such as the Mirage and Rafale jet fighters, account for much of the remainder. The founding Dassault family owns just over half of the company; EADS owns about 46%.[106]	Focal points of the company's strategy for the future are:[107] a new business jet; projects on environmentally-friendly, executive aircraft; -a range of unmanned combat aircraft and observation drones. Diversifying into electronics through a French government brokered stake in Thales and through Dassault systems software Dassault continues to expand into the new arenas of defense technology sovereignty.	Combat aircraft are instruments of political independence.[108] Maintaining an independent French ability to build fighter aircraft is at the heart of the French notion of assured sovereignty. As stated elsewhere on the company web page Dassault is an architect of complex airborne systems, and expert in the main sovereignty technologies.	Relying on French orders as however, the size of the French defense market in shrinking budgets will be key. The offset to this is in the French Governments willingness to use political and diplomatic channels to encourage or offset Dassault sales overseas. [109]	As described in the company strategy as "innovative cooperation paradigms" International government lead sales or a government managed merger are both likely ways ahead.

APPENDIX 4 – Strike Fighter Market Firm Analysis

SAAB	The aeronautics arm includes aero structures, airborne systems and unmanned aircraft. Security and Defense focuses on military/aircraft product support and logistics, as well as communications and surveillance systems for both the civil and military sectors.	SAAB corporate strategy identified to following important market driving forces [110] New security needs in flow-based society. New forms of co-operation. Higher percentage of self-financed R&D. Partnerships between public and private players. Need for broad, deep, long-term solutions. Local presence can be a decisive Macroeconomic impact. [111]	SAAB is the primary supplier of aircraft to the Swedish Air Force.[112] The Swedish government has not given large subsidies to SAAB. The government has declared fighters a key industrial segment and will preserve the Gripen through 2040. SAAB has provided much of the spin-off benefits in technology and production techniques to the Swedish economy	SAAB markets the Gripen fighter as an affordable, multi role, high technology (advanced radar and net centric) fighter aircraft. It has had some export success with smaller air forces that have limited budgets and with countries that have larger buys and desire industrial and technology transfer opportunities.	SAAB has identified three shifts that are gradually affecting its position and operations.[113] Strictly Swedish -> more internationally active Traditional defense -> more civil security. Product-focused industry -> more service supplier focused on solutions The growing importance of being a sub system provider in areas of expertise to others in the commercial and military markets

APPENDIX 5 – JSF Supply Chain Management in the Drive to Affordability and Reliability

The F-35 JSF supply chain management concept potentially creates a breakthrough the U.S. and its allies need in an era of skyrocketing entitlements programs and thinning defense budgets. However, a March 2011 Government Accounting Office report noted "managing an extensive, still-maturing global network of suppliers adds another layer of complexity to producing aircraft efficiently and on-time."[114] A product's supply chain represents the cumulative efforts of multiple companies. Historically, many companies looked internally at their own processes and materials to create efficiencies. In reality, effective supply chain management involves active supervision of the network of interconnected organizations to maximize customer value. Supply chains include everything from raw materials, individual components, sub-assemblies, major assemblies and finished products. Actively monitoring production and transportation of these assets upstream and downstream underscores an essential aspect of supply chain management. In today's networked, world infused with real time data, detailed supply information exists just a click away. A cutting edge aircraft like the F-35 literally requires thousands of suppliers from around the world integrated throughout its supply chain.[115]

An analysis of the Joint Strike Fighter's supply chain management concept needs to begin with an evaluation of the F-35 manufacturing process. Joint Strike Fighter final assembly occurs at Lockheed Martin's Fort Worth facility. During a visit to the facility on 8 April 2011, many processes were observed first hand. The Fort Worth facility represents a long history of producing aircraft dating to World War II. More recently, the facility served as home of the F-16 Falcon production line and a portion of the F-22 Raptor. Most of the F-16 work shifted to another building at the Fort Worth site and F-22 manufacturing equipment was containerized and moved to a storage location in case it is ever required in the future. The main industrial building now houses the F-35 final assembly line in which many lean manufacturing principles are readily evident.

A key attribute identifiable throughout the facility is the **concept of 5-S**. The principles of 5-S employed by Lockheed Martin include sort, set in order, shine, standardize, and sustain.[116] The facility sorts out items that are not needed for production and only necessary equipment remains located within shop areas. Work is standardized through use of electronic technical manuals and prescribes very exacting procedures for each technician working on the aircraft and its systems. Correct procedures and processes are ingrained throughout the facility and proper manufacturing techniques are sustained on the production floor.

The production line illustrates a basic **Kanban method** to ensure efficient and orderly flow of materials. Work cells are organized across the production flow in order for team members to gain proficiency on specific tasks. Teams rely on point-of-use modus operandi for materials and tools necessary to complete tasks. Tools are staged in the immediate work area and materials are delivered directly to mechanics. Point-of-use mode slashes excess motions for mechanics moving throughout the building to retrieve assets. Aircraft production phases gain efficiency by avoiding overproduction of assemblies.

A detailed work breakout package meticulously forecasts when specific components will be required and prevents excess inventory. Material forecasts are pushed upstream to suppliers so they can accurately predict requirements according to each items production lead times. This forecasting averts storage problems at the facility for aircraft components not immediately required. The assembly line's detailed forecasting aids suppliers by avoiding a bullwhip effect in which long term forecasts become increasingly more unreliable. A steady forecast of total aircraft required to be built each year enables second and third tier suppliers to avoid radical

manufacturing inaccuracies. At the same time, fixed requirements prevent excess work-in-process at the Fort Worth facility and for suppliers. Overall work-in-process reductions allow for optimum material costs and ultimately aim to lower the price per unit of aircraft. Many parts of the aircraft are produced using automated high-tech machining and drilling. By removing human touch-labor at many steps and incorporating robotics the company greatly reduced defects and rework. Compared to legacy weapon systems, the F-35 relies heavily on precisely fitting aircraft structures which are only possible through the use of costly computerized industrial machines.[117]

At the operational level, success of an F-35 performance based logistics system hinges upon worldwide fleet health visibility. The nerve center of fleet wide visibility consists of an embedded system in the aircraft known as **autonomic logistics information system (ALIS).** ALIS will look globally at every aspect of the aircraft and its support base. ALIS catalogs all maintenance activities on each aircraft, provides debrief data from aircrews, identifies where spare parts are located, monitors fleet health and even tracks individual training certifications for maintenance technicians. This wealth of data will be funneled to a Joint Sustainment Operations Center to facilitate an innovative concept of operations for global distribution of assets and central management of the fleet.[118] The challenge associated with this concept of operations is who gets the last part on the shelf when two different services or countries need the same item. Parts shortage will eventually happen and there will come a time when priorities need to be set as to who gets the last serviceable asset. The problem becomes even more complex when replacement spares may take several weeks to procure and aircraft will sit non-mission capable without serviceable line replacement units. When questioned about this conundrum, a senior Lockheed Martin supply chain specialist could not provide a definitive response.

The challenge of spare parts shortages evolves from how to accurately forecast and preposition spares that will be consumed while operating the aircraft. Lockheed studied whether or not to use a third party logistics system for warehouses management of spares and where to optimally locate warehouses. The proposed spares replenishment process adheres to a linear flow through the logistics pipeline. A supplier manufactures a part for entry into the pipeline. The asset is then priority shipped next day air to a warehouse and shelved by a third party logistics contractor. These same contractors will priority ship outbound spares from the warehouse when a demand is created by the aircraft user. Each time the user creates a demand in the system the original equipment manufacturer will automatically push a new spare to the warehouse to maintain a fixed safety stock level. In the United States, warehouses will be located at bi-coastal locations to be more cost effective and lower overall risk for meeting service levels. Transportation costs for spares are expected to be minimal since 86% of parts weigh ten pounds or less and will follow a zone-based pricing structure used by small parcel carriers. European and Asian spares processing will conform to similar linear movements. The primary difference will be the addition of taxes and duties as spare parts move into and out of warehouses. Lockheed predicts the highest cost driver for material processing to be warehousing costs.[119]

The challenge with spare part distribution lies in accurately modeling the consumption rates so fixed levels can be allocated to the warehouses. **Key performance parameters** Lockheed must meet for the F-35 program are 98% mission reliability, 30% increase in sortie generation rate and 21% cost reduction.[120] However, the F-35 still does not have a model that fits each service and each country's spares ordering and replenishment patterns. Getting buy-in and participation from all the stakeholders for a one-size-fits-all method may prove to be more

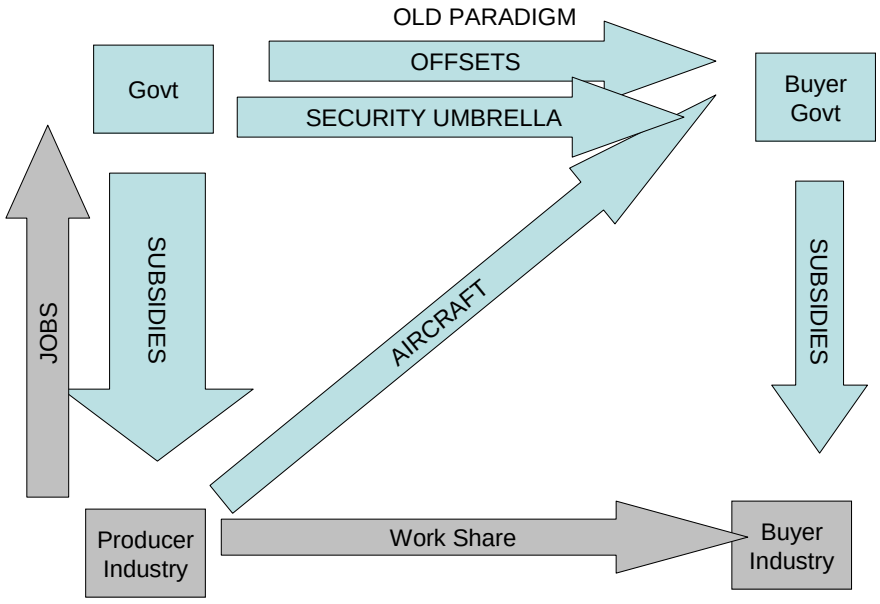
challenging than expected. Furthermore, spares will be released to customers based upon fixed mission capable rates each service or country established for its respective fleet of aircraft. Number of spares apportioned to the service will be driven by defense funding levels associated with a set mission capable rate; contrasted against an organizational level maintenance unit's attempts to ideally strive for a 100% mission capable rate. Units will still be accountable to their respective higher headquarters for performance. The problem is services measure aircraft mission capable rates and availability data differently. Therefore, Lockheed struggles with developing a standardized method of support. Operational units will become frustrated when they want to obtain parts but cannot receive them due to performance based logistics restrictions.

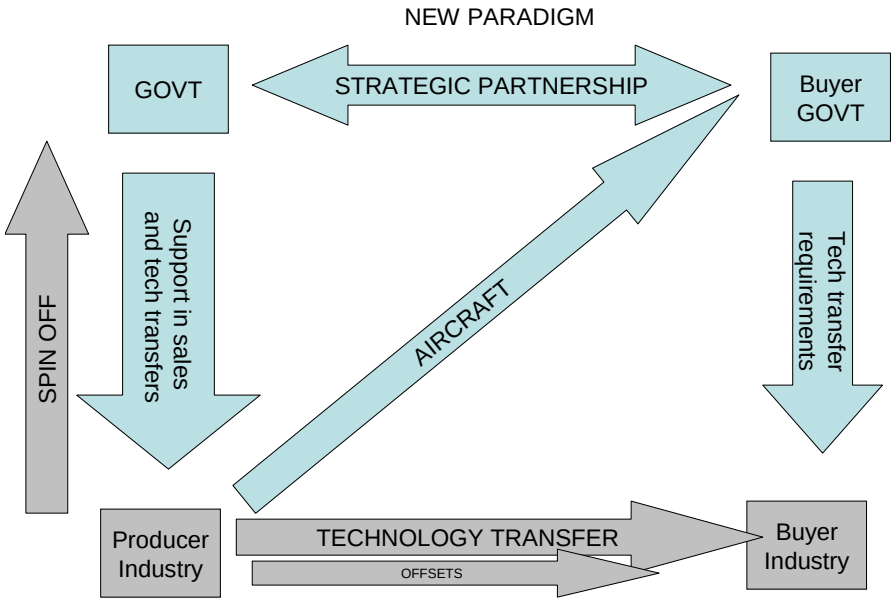
In order to gain supply chain efficiencies and globally distribute the parts and materials, the F-35 must be interoperable across an entire fleet of 3,000 aircraft. Lockheed claims each aircraft is the same version and contains the same parts as all other aircraft. Even though the program includes a conventional, carrier based and vertical/short take off and landing versions, Lockheed argues they will still contain the same components. This results in one common supply chain for distribution of parts to any U.S. service or partner country. As this supply chain matures, each country will be dependent upon each other to manufacture and distribute parts. No single country can support the aircraft by itself. The aircraft contains nearly 40,000 different parts supplied from thousands of first, second and third tier companies. A crux of the program's success will be gaining in-depth knowledge of a contractor's ability to deliver components and services as expected. Most often government acquisition offices boast excellent knowledge about prime contractors but do not have sufficient knowledge about performance and business strategies of lower level contractors. Lockheed must tighten management controls for quality and reliability at the sub-tier supplier level to prevent unapproved material changes.[121]

JSF Supply chain risk assessment

This brings to light the fragility of supply chains that rely on a single source of supply. During the March 2011 earthquake and tsunami that devastated Japan many of the most important aircraft parts suppliers to the U.S. were indirectly impacted. First tier suppliers such as Fuji, Kawasaki and Mitsubishi were well away from the earthquake's epicenter so their facilities and personnel suffered very little destruction. Conversely, second and third tier suppliers that provide consumables and components to the prime contractors were seriously damaged by the earthquake. As a result, the first tier companies stated they would incur work stoppages unless they found alternatives sources of supply. This emphasizes the fragility of a supply chain that relies heavily on just in time logistics. Unpredictable interruptions to a supply chain's second or third tier companies can seriously hinder the primary contractor's ability to produce on schedule. This scenario raises the question of obtaining dual sources of supply for key components. Dual sources may be feasible for consumables with high economies of scale, but is not necessarily practical for high priced components.[122] As F-35 program managers evaluate the acquisition strategy for weaknesses and threats, they definitely need to consider the fragility of a supply chain that relies upon single sources of supply for key materials.

APPENDIX 6 – MARKET CHANGES AND BEHAVIOR





APPENDIX 6 – MARKET CHANGES AND BEHAVIOR

INTERNATIONAL MARKET

(BIG PLAYERS MILITARY AND COMMERCIAL)

	PRODUCE OR BUY	SUBSIDIES TO INDUSTRY	OFFSETS	TECH TRANSFERS
USA	**PRODUCE**	YES BUT NO LONGER SUSTAINABLE	PROVIDED BY INDUSTRY ONLY. USG INVOLVEMENT PROHIBITED	VERY RESTRICTIVE
FRANCE	**PRODUCE**	YES BUT NO LONGER SUSTAINABLE	NO FORMAL POLICY. HAS A GOVT OFFSET DEPT	VERY WILLING
EUROPE CONSORTIUM	**PRODUCE**	YES BUT NO LONGER SUSTAINABLE	ROADMAP TO ELIMINATE OFFSETS WITHIN EU. COMMERCIAL PRACTICE OUTSIDE EU.	VERY WILLING
SWEDEN	**PRODUCE**	YES	POLICY REQUIRES OFFSETS FOR DEFENSE PURCHASES	WILLING BUT CONSTRAINED WITH US CONTENT
INDIA	**BUY**	YES	REQUIRED BY GOVT POLICY	REQUIRES TECH TRANSFERS
BRAZIL	**BUY MILITARY PRODUCE COMMERCIAL**	YES	REQUIRED BY GOVT POLICY	REQUIRES TECH TRANSFERS
CANADA	**BUY MILITARY PRODUCE COMMERCIAL**	YES	REQUIRED BY GOVT POLICY	WILLING FOR COMMERCIAL SALES
RUSSIA	**PRODUCE**	YES	NO POLICY FOUND	YES BUT OF LIMITED VALUE
CHINA	**PRODUCE MILITARY BUY COMMERCIAL**	YES	OFFSETS REQUIRED	DEMANDS

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